Total Maximum Daily Load Development for the James River Basin

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EXECUTIVE SUMMARY

Water Quality Impairments

Totier Creek and Ballinger Creek in southern Albemarle County and Rock Island Creek and the Slate River in Buckingham County were placed on the 303(d) list for not supporting the recreational use. These streams drain directly to the James River. In addition, four tributaries to the Slate River and an upstream Slate River segment in Buckingham County were found not to be supporting the recreational use. Therefore TMDLs are required for nine impaired segments in Albemarle and Buckingham Counties. These impaired segments are described below.

Frisby Branch (VAC-H21R-02) begins at the headwaters at river mile 3.93 and extends to its confluence with Grease Creek. Frisby Branch was assessed as Partially Supporting on the 2004 impaired waters list due to violations of the instantaneous fecal coliform water quality standard found in 2 of 8 samples taken at station 2-FRY000.35 and 4 of 9 samples taken at 2-FRY003.00. Frisby Branch was initially placed on the 303(d) list in 2002.

The Austin Creek impairment begins at the headwaters and extends downstream to the confluence with the North River (6.14 stream miles). Fecal concentrations exceeded the instantaneous water quality standard in 3 of 9 samples taken at 2-AUS001.12. Austin Creek was initially placed on the 303(d) list in 2002.

Troublesome Creek was listed as impaired because fecal coliform counts exceeded the instantaneous water quality standard in 2 of 9 samples taken at 2-TBM000.80 in the 2004 305(b)/303(d) integrated water quality report. The impaired segment begins at the headwaters and extends to the confluence with the Slate River (0.95 stream miles). Troublesome Creek was initially placed on the 303(d) list in 2004.

The North River (VAC-H21R-03) impairment begins at the confluence with Meadow Creek at river mile 8.44 and ends at the mouth at the Slate River (river mile 0.00). Fecal coliform counts exceeded the instantaneous water quality standard in 5 of 21 samples taken at 2-NTH001.65 and 7 of 9 samples taken at 2-NTH003.88. The North River was initially placed on the 303(d) list in 2002.

Rock Island Creek in Buckingham County (VAV-H17R-04) was listed as impaired because three fecal coliform instantaneous water quality standard violations out of 19 samples taken at station 2-RKI003.40. The impairment begins at the headwaters at river mile 8.84 and ends at the James River confluence at river mile 0.00. Rock Island Creek was initially placed on the 303(d) list in 2004.

Two Slate River impairments are listed. The Slate River (VAC-H21R-04) begins at the confluence with Grease Creek (river mile 34.93) and ends at the confluence with Walton Fork (river mile 21.65) for a total 13.28 stream miles. Fecal coliform counts exceeded the instantaneous standard in 3 of 10 samples taken at 2-SLT024.72 and in 5 of 9 samples taken at 2-SLT030.19.

The second Slate River segment (VAC-H22R-01) begins at the confluence with Sharps Creek and extends to the mouth of the James River for a total of 7.12 stream miles. Fecal coliform bacteria exceeded the instantaneous standard in 4 of 27 samples taken at 2-SLT003.88. Both Slate River impairments were initially placed on the 303(d) list in 2002.

Ballinger Creek was listed on the 2004 305(b)/303(d) Water Quality Assessment Integrated Report because fecal coliform counts exceeded the instantaneous water quality standard in three of 13 samples taken at 2-BLR003.00. The impaired segment begins at the headwaters and extends to the confluence with the James River (9.82 stream miles). Ballinger Creek was initially placed on the 303(d) list in 2004.

The Totier Creek impairment (VAV-H17R-01) begins at the headwaters (river mile 11.29) and ends at the James River confluence (river mile 0.00). Totier Creek was listed as impaired because there were 13 fecal coliform instantaneous water quality standard violations out of 49 samples taken at VADEQ station 2-TOT002.61. Totier Creek was initially placed on the 303(d) list in 2002.

TMDL Development

A TMDL (Total Maximum Daily Load) must be established for each impaired segment. A TMDL represents the total amount of a pollutant a water body can contain and still meet water quality standards.

Fecal Coliform Bacteria

Fecal coliform bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard. The E. coli water quality standard was adopted because there is a stronger correlation between the concentration of these organisms (*E. coli* and *enterococci*) and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and *enterococci* standard became effective in Virginia on January 15, 2003. For this TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126-cfu/100 mL and a single sample maximum of 235-cfu/100 mL. A translator developed by VADEQ was used to convert fecal coliform values to *E. coli* values.

Modeling Procedures

Hydrology

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and fecal coliform loads.

For purposes of modeling the streamflow and fecal bacteria concentrations in the impaired streams, the drainage area was divided into 41 subwatersheds.

The Slate River gage #02030500 near Arvonia was utilized to calibrate the hydrology of the nine impaired watersheds. A hydrologically stable time period used for hydrologic calibration covered the period 10/1/1992 through 9/30/1995. A hydrology validation period of 10/1/1987 through 9/30/1990 was used.

The fecal coliform calibration for the impairments in the James River Tributaries in Albemarle and Buckingham Counties was conducted using monitored data collected at VADEQ monitoring stations. Modeled fecal coliform levels closely resembled observed levels indicating that the model was well calibrated. A water quality calibration period of 10/1/1996 – 9/30/1999 was used in the model. The validation period was 10/1/1999 – 9/30/2001.

Existing Conditions

Fecal Coliform Bacteria

Potential sources of fecal coliform bacteria include both point source and nonpoint source (NPS) contributions. Nonpoint sources include: wildlife, grazing livestock, land application of manure and biosolids, urban/residential runoff, failed and malfunctioning septic systems, and uncontrolled discharges (straight pipes). There are currently three active point sources in the Slate River watershed that are permitted for bacterial removal. In addition there are six single-family general wastewater permits in the Slate River watershed. These discharges are small (<1,000 g/day) and are expected to meet the 126-cfu/100 mL *E. coli* standard.

Wildlife populations, the rate of failure of septic systems, domestic pet populations, and numbers of livestock in the Slate River and southern Albemarle County impairments are examples of land-based nonpoint sources used to calculate fecal coliform loads. Also represented in the model were direct nonpoint sources of uncontrolled discharges, direct deposition by wildlife, and direct deposition by livestock. Contributions from all of these sources were updated to 2006 conditions to establish existing conditions for the watershed. The calibrated HSPF model predicted violations of both the instantaneous and geometric mean standards throughout the impaired watersheds when the model was run using existing conditions.

Load Allocation Scenarios

The next step in the bacteria TMDL process was to reduce the various source loads within the model to levels that would result in attainment of the water quality standards. Because Virginia's *E. coli* standard does not permit any exceedances of the standard, modeling was conducted for a target value of 0% exceedance of the geometric mean standard and 0% exceedance of the single sample maximum *E. coli* standard. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. The final TMDL loads are shown in Tables ES.1 through ES.9.

The following are the recommended load allocation scenarios for the nine impairments:

Frisby Branch

- 0% reductions in direct wildlife loads,
- 0% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99.3% reductions in NPS loads from agricultural and urban/residential areas, and
- 100% reductions in loads from straight pipes.

Austin Creek

- 50% reductions in direct wildlife loads,
- 90% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99% reductions in NPS loads from agricultural and urban/residential areas, and
- 100% reductions in loads from straight pipes.

Upper Slate River

- 99% reductions in direct wildlife loads,
- 99% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99.5% reductions in NPS loads from agricultural
- 99% reductions in NPS loads from urban/residential areas, and
- 100% reductions in loads from straight pipes.

North River

- 97% reductions in direct wildlife loads,
- 97% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99.5% reductions in NPS loads from agricultural and urban/residential areas, and
- 100% reductions in loads from straight pipes.

Troublesome Creek

- 0% reductions in direct wildlife loads,
- 0% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99% reductions in NPS loads from agricultural areas,
- 80% reductions in NPS loads from urban/residential areas, and
- 100% reductions in loads from straight pipes.

Lower Slate River

- 60% reductions in direct wildlife loads,
- 60% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99% reductions in NPS loads from agricultural and urban/residential areas, and
- 100% reductions in loads from straight pipes.

Rock Island Creek

- 84% reductions in direct wildlife loads,
- 84% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99% reductions in NPS loads from agricultural and urban/residential areas, and
- 100% reductions in loads from straight pipes.

Ballinger Creek

- 51% reductions in direct wildlife loads,
- 51% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99% reductions in NPS loads from agricultural and urban/residential areas, and
- 100% reductions in loads from straight pipes.

Totier Creek

- 1% reductions in direct wildlife loads,
- 1% reductions in NPS wildlife loads
- 100% reductions in direct livestock loads,
- 99% reductions in NPS loads from agricultural and urban/residential areas, and
- 100% reductions in loads from straight pipes.

Table ES.1 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Frisby Branch watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Frisby Branch	2.15E+10	2.15E+12	*Implicit*	2.17E+12
Future Growth	2.15E+10			

Table ES.2 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Austin Creek watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Austin Creek	1.62E+10	1.63E+12	*Implicit*	1.65E+12
Future Growth	*1.62E+10*			

Table ES.3 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Upper Slate River watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Upper Slate River	4.22E+10	1.41E+13	*Implicit*	1.41E+13
VA0063291	*8.70E+09*			
VA0087563	*5.57E+09*			
Future Growth	*2.79E+10*			

Table ES.4 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Troublesome Creek watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Troublesome Creek	5.23E+10	*2.69E+12*	*Implicit*	2.74E+12
VA0063291	*8.70E+09*			
Future Growth	*4.36E+10*			

Table ES.5 Average annual *E. coli* loads (cfu/year) modeled after allocation in the North River watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
North River	5.52E+10	5.57E+12	*Implicit*	5.63E+12
Future Growth	*5.52E+10*			

Table ES.6 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Lower Slate River watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Lower Slate River	3.19E+12	5.38E+13	*Implicit*	5.70E+13
VA0063291	*8.70E+09*			
VA0066460	*5.22E+11*			
VA0087563	*5.57E+09*			
VAG404041	*6.96E+08*			
VAG404116	*1.74E+09*			
VAG404166	*1.74E+09*			
VAG407204	*8.70E+08*			
VAG407237	*1.57E+09*			
VAG407251	*7.83E+08*			
Future Growth	*2.65E+12*			

Table ES.7 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Rock Island Creek watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Rock Island Creek	3.38E+10	3.38E+12	*Implicit*	3.41E+12
Future Growth	*3.38E+10*			

Table ES.8 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Ballinger Creek watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Ballinger Creek	5.75E+10	5.76E+12	*Implicit*	5.82E+12
Future Growth	*5.75E+10*			

Table ES.9 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Totier Creek watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Totier Creek	1.62E+11	1.75E+13	*Implicit*	1.77E+13
Future Growth	*1.62E+11*			

Correcting all straight pipes, reducing nonpoint agriculture and urban/residential loads and reducing direct livestock loads results in a violation rate of the instantaneous standard less than 10.5% in all nine impaired watersheds and is the Stage 1 implementation goal.

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in this process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the impairments the James Tributaries in Albemarle and Buckingham Counties. The second step is to develop a TMDL implementation plan (IP). The final step is to implement the TMDL IP and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act (CWA) and current United States Environmental Protection Agency (EPA) regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and waste load allocations can and will be implemented. Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate waterbody. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource.

Once a TMDL is developed and approved by the State Water Control Board (SWCB) and EPA, measures must be taken to reduce pollution levels in the stream. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the "Board shall develop and implement a plan to achieve fully supporting status for impaired waters". The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), to be implemented in a staged process.

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, to address the bacteria TMDL, reducing the human bacteria loading from straight pipes and failing septic systems should be a primary implementation focus because of the health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system installation/repair program. Livestock exclusion from streams has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the direct cattle deposits and by providing additional riparian buffers. Reduced trampling and soil shear on streambanks by livestock has been shown to reduce bank erosion.

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. The state must also demonstrate that attaining the designated use is not feasible. Information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens as well as EPA will be able to provide comment during this process.

Public Participation

During development of the TMDL for the nine impairments in the James River Tributaries in Albemarle and Buckingham Counties, public involvement was encouraged through two public meetings and two Local Steering Committee (LSC) meeting. An introduction of the agencies involved, an overview of the TMDL process, and the specific approach to developing the James River Tributaries in Albemarle and Buckingham Counties TMDLs were presented at the first of the public meetings. Details of the pollutant sources were also presented at this meeting. Public understanding of, and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The final model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting and one written comment was received. Watershed stakeholders will also have the opportunity to participate in the development of the TMDL IP.

1. INTRODUCTION

1.1 Background

The Clean Water Act (CWA) that became law in 1972 requires that all U.S. streams, rivers, and lakes meet certain water quality standards. The CWA also requires that states conduct monitoring to identify polluted waters or those that do not meet standards. Through this required program, the state of Virginia has found that many stream segments do not meet state water quality standards for protection of the five beneficial uses: recreation, aquatic life, wildlife, fishing/shellfishing, and drinking.

When streams fail to meet standards, Section 303(d) of the CWA and the U.S. Environmental Protection Agency's (EPA) Water Quality Management and Planning Regulation (40 CFR Part 130) both require that states develop a Total Maximum Daily Load (TMDL) for each pollutant. A TMDL is a "pollution budget" for a stream. That is, it sets limits on the amount of pollution that a stream can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and nonpoint source loadings are considered. A TMDL accounts for seasonal variations and must include a margin of safety (MOS). Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

Once a TMDL is developed and approved by EPA, measures must be taken to reduce pollution levels in the stream. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the *"Board shall develop and implement a plan to achieve fully supporting status for impaired waters"*. The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), which should be implemented in a staged process.

This report deals with the tributaries to the James River that are located in Albemarle and Buckingham counties; this portion of the James River watershed is contained in USGS

Hydrologic Unit Code 02080203 (Figure 1.1). The watersheds included in Albemarle County are Totier Creek and Ballinger Creek. There has been a general decline in intense agricultural activity in these watersheds over the past 10 years. Several large cattle farmers have left the business and farm acreage is being converted to residential or small farm (<25 acres) use. Since the 1998 census, there has been a projected 6% increase in population in these watersheds. The Virginia Department of Health (VDH) has initiated a well permitting program to protect ground water. The county recently passed a voluntary stream-buffering ordinance.

The watersheds included in Buckingham County include Rock Island Creek and the Slate River. There has been a projected 1.5% increase in population since the 1998 census. According to the Virginia Tech Extension Service, there has also been an increase in the number of beef cattle in these watersheds. Logging is the dominant land use in Buckingham County. Westvaco owns or leases a considerable amount of land in the county. Approximately 1,084 acres are logged in the Rock Island and Slate River watersheds every year. This figure includes both thinning and clearcutting.

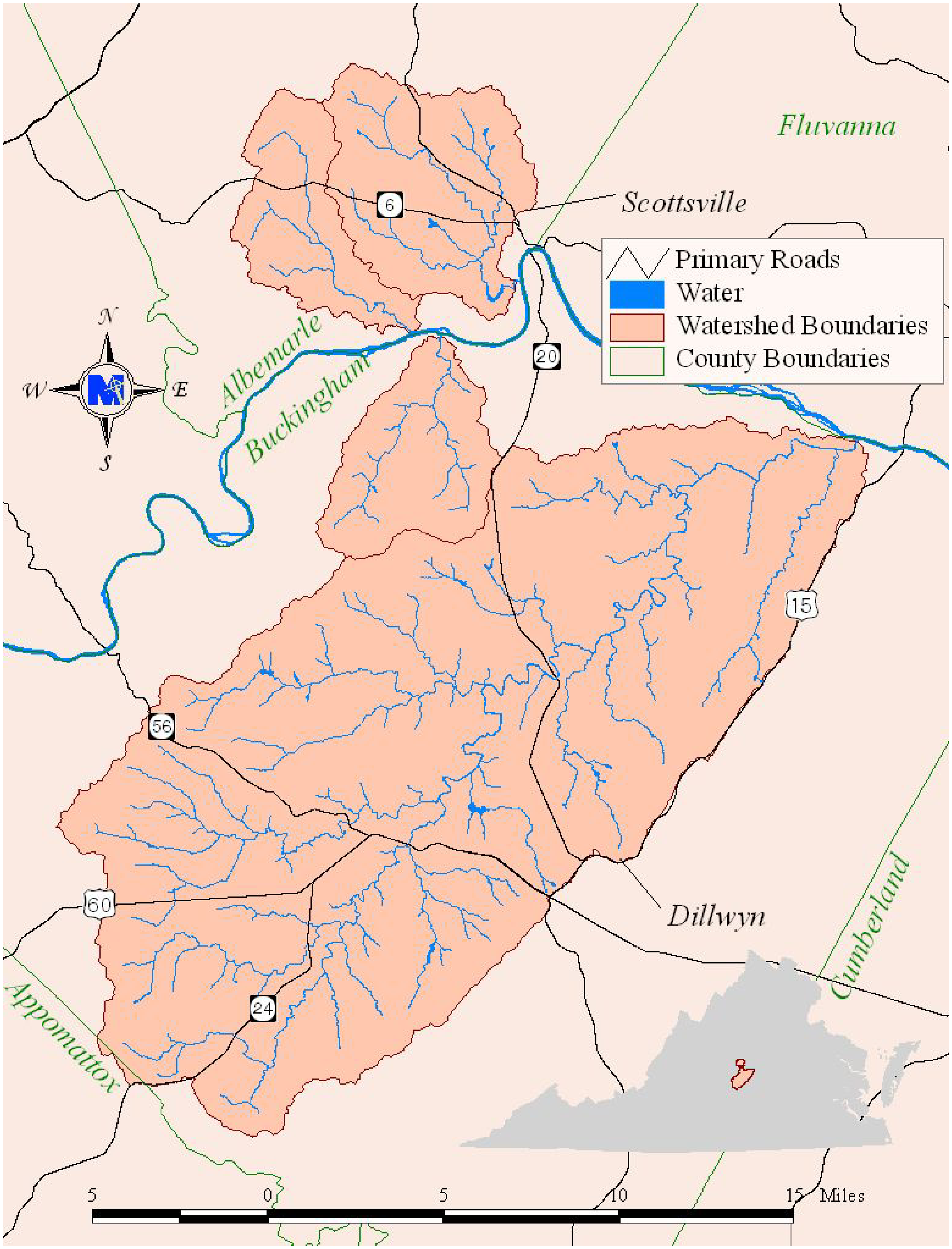

Figure 1.1 Location of the James River Tributaries in Albemarle and Buckingham Counties.

The impaired segments of Ballinger Creek and Totier Creek are in southern Albemarle County. Buckingham County includes impairments to Austin Creek, Frisby Branch, North River, Rock Island Creek, Slate River, and Troublesome Creek (Figure 1.2). The Virginia Department of Environmental Quality (VADEQ) has identified all of these segments as impaired with regard to fecal coliform. For the purposes of this report, all of these watersheds shall be referred to as the "James River Tributaries in Albemarle and Buckingham Counties".

Both Slate River segments, Frisby Branch, North River, and Totier Creek segments were placed on the *2002 Section 303(d) Report on Impaired Waters*. All segments remained on the *2004 Section 305(b)/303(d) Water Quality Assessment Integrated Report*; in addition, the Austin Creek, Ballinger Creek, Rock Island Creek and Troublesome Creek segments were added. Elevated levels of fecal coliform bacteria recorded at VADEQ ambient water quality monitoring stations showed that these James River Tributaries in Albemarle County and Buckingham County stream segments do not support the recreational use.

Austin Creek (VAC-H21R-01) was first listed for fecal coliform violations on the *2004 305(b)/303(d) Water Quality Assessment Integrated Report*. It was designated as not supporting the recreational use due to fecal coliform violations in 3 of 9 monitoring events at VADEQ monitoring station 2-AUS001.12. The segment remained on the 2006 *305(b)/303(d) Water Quality Assessment Integrated Report* due to fecal coliform violations in 1 of 1 sampling events at VADEQ monitoring station 2-AUS001.12. The impaired segment begins at the headwaters at river mile 6.14 and extends to the mouth at North River (river mile 0.00).

Ballinger Creek (VAV-H17R-03) was first listed on the *2004 305(b)/303(d) Water Quality Assessment Integrated Report* for not supporting the recreation use. During the 2004 assessment period, samples taken at VADEQ station 2-BLR003.00 resulted in fecal coliform violations in 3 of 13 samples. The segment remained on the 2006 *305(b)/303(d) Water Quality Assessment Integrated Report* due to fecal coliform violations in 2 of 6 sampling events at VADEQ monitoring station 2-BLR003.00. The impairment begins at the headwaters at river mile 9.82 and ends at the James River confluence (river mile 0.00).

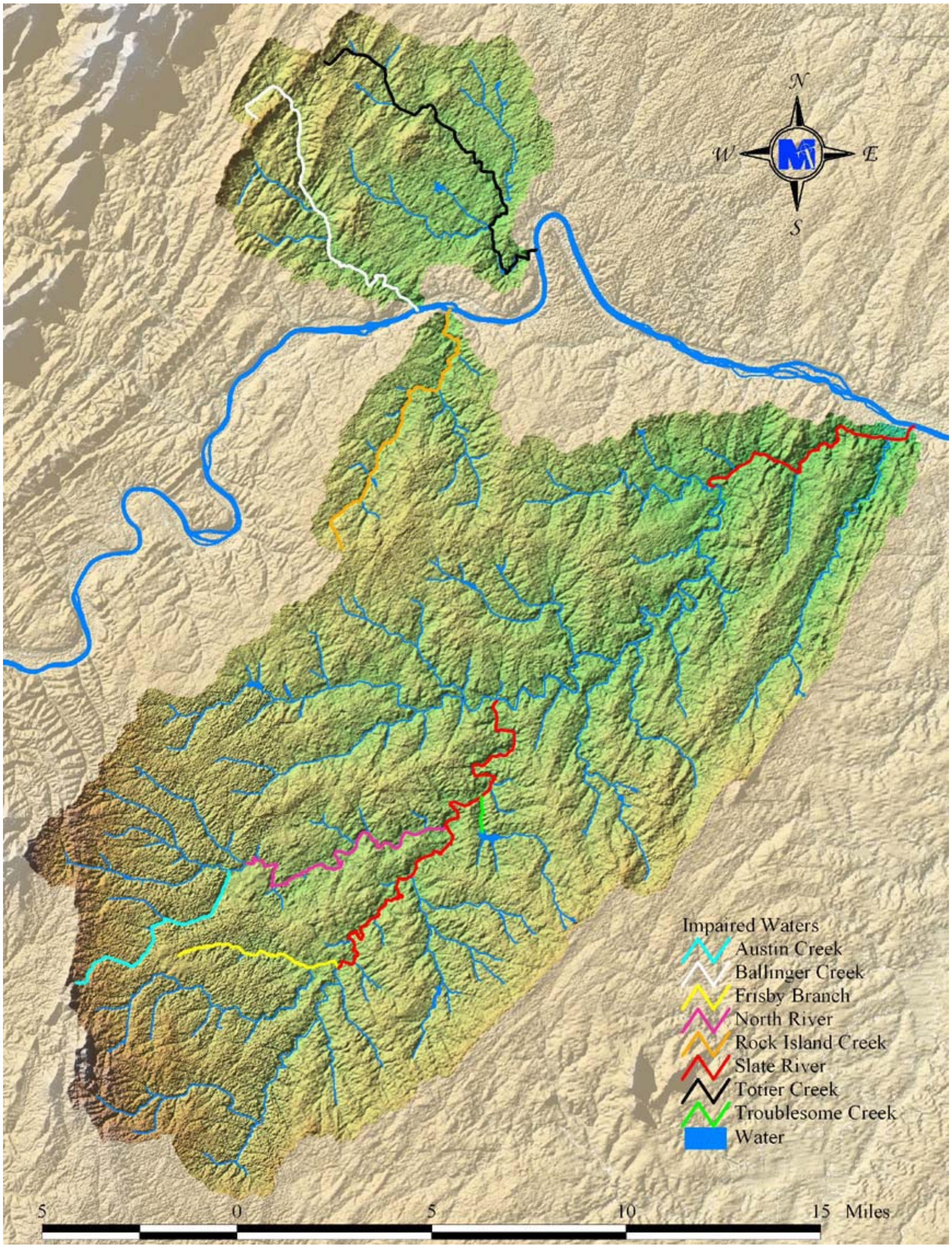

Figure 1.2 Impaired stream segments in the James River Tributaries in Albemarle and Buckingham Counties.

Frisby Branch (VAC-H21R-02) appeared on the *2002 303(d) Report on Impaired Waters* as Partially Supporting the recreational use due to high fecal coliform counts found in 2 of 6 samples taken at station 2-FRY000.35. At this time, the impaired segment was designated as beginning at the headwaters at river mile 3.74 and extending to an unnamed tributary at river mile 2.40. Frisby Branch was included again on the 2004 *305(b)/303(d) Water Quality Assessment Integrated Report* for fecal coliform violations in 4 of 9 samples and 2 of 8 sampling events at monitoring stations 2-FRY003.00 and 2-FRY000.5 respectively. The segment size was adjusted to beginning at river mile 3.93 and ending at the mouth at Grease Creek (river mile 0.00) as a result of the National Hydrography Dataset used during the 2004 cycle. The segment remained on the 2006 *305(b)/303(d) Water Quality Assessment Integrated Report* for fecal coliform violations in 1 of 1 sampling events at monitoring station 2-FRY000.35.

North River (VAC-H21R-03) was first listed in the *2002 303(d) Report on Impaired Waters* for not supporting the recreation use due to excessive counts of fecal coliform bacteria. High counts were found in 5 of 21 samples taken at VADEQ monitoring station 2-NTH001.65. The impairment begins at the confluence with Meadow Creek at river mile 8.44 and ends at the mouth at the Slate River (river mile 0.00). The same segment appeared on the 2004 *305(b)/303(d) Water Quality Assessment Integrated Report* fecal coliform violations in 5 of 36 and 7 of 9 sampling events at VADEQ monitoring stations 2-NTH001.65 and 2-NTH003.88 respectively. The segment remained on the 2006 *305(b)/303(d) Water Quality Assessment Integrated Report* due to fecal coliform violations in 1 of 1 sampling events at VADEQ monitoring stations 2-NTH001.65 and 2-NTH003.88.

Rock Island Creek in Buckingham County (VAV-H17R-04) appeared on the *2004 305(b)/303(d) Water Quality Assessment Integrated Report* for fecal coliform violations in 3 of 19 sampling events at VADEQ monitoring station 2-RKI003.40. The segment remained on the 2006 *305(b)/303(d) Water Quality Assessment Integrated Report* for fecal coliform violations in 2 of 7 sampling events at VADEQ monitoring station 2-

RKI003.40. The impairment begins at the headwaters at river mile 8.84 and ends at the James River confluence at river mile 0.00.

Two Slate River impairments are listed. The Slate River (VAC-H21R-04) impairment was first noted on the *2002 303(d) Report on Impaired Waters.* In that listing, the impaired segment was designated as beginning at the confluence with Bryant Creek (river mile 24.25) and ending at the confluence with Ripley Creek (river mile 11.37), a 12.88-mile segment. The segment was not supporting the recreation use due to fecal coliform violations in 3 of 10 sampling events at VADEQ monitoring station 2-SLT024.72, a CAFO special study station.

This impairment (Slate River VAC-H21R-04) was adjusted as a result of the National Hydrography Dataset used during the 2004 *305(b)/303(d) Water Quality Assessment Integrated Report*. The segment was now 13.28 miles long, beginning at the confluence with Grease Creek (river mile 34.93) and ending at the confluence with Walton Fork (river mile 21.65). The segment was not supporting the recreational use due to fecal coliform violations in 3 of 9 sampling events at monitoring station 2-SLT024.72 and in 5 of 9 sampling events at monitoring station 2-SLT030.19, CAFO special study stations.

The second Slate River segment (VAC-H22R-01) was also listed for the first time on the 2002 303(d) impaired waters list. The segment began at river mile 3.64 and ended at the mouth of the James River (river mile 0.00). This segment was Partially Supporting for recreation use due to fecal coliform bacteria violations in 4 of 26 sampling events at VADEQ monitoring station 2-SLT003.88. In the *2004 305(b)/303(d) Water Quality Assessment Integrated Report,* this Slate River segment was reconfigured as beginning at the confluence with Sharps Creek at river mile 7.12 and extending to the mouth of the James River (river mile 0.00.) It was designated Not Supporting for the recreational use due to fecal coliform violations in 4 of 27 sampling events at VADEQ monitoring station 2-SLT003.88. The segment remained on the *2006 305(b)/303(d) Water Quality Assessment Integrated Report* for fecal coliform violations in 4 of 26 sampling events at VADEQ monitoring station 2-SLT003.88.

The Totier Creek impairment (VAV-H17R-01) begins at the headwaters (river mile 11.29) and ends at the James River confluence (river mile 0.00). Totier Creek was first listed on the *2002 303(d) Report on Impaired Waters* as only Partially Supporting the recreational use due to fecal coliform violations in 7 of 57 sampling events at VADEQ monitoring station 2-TOT002.61. fecal coliform water quality standard violations out during the 2002 assessment period. The segment was listed on the 2004 *305(b)/303(d) Water Quality Assessment Integrated Report* for fecal coliform violations in 13 of 79 sampling events at monitoring station 2-TOT002.61. The segment remained on the 2006 *305(b)/303(d) Water Quality Assessment Integrated Report* due to fecal coliform violations in 8 of 34 samples at VADEQ monitoring station 2-TOT002.61.

The second Slate River segment and the Totier Creek segment were listed in Attachment B of the 1998 consent decree as “Plaintiff’s Waters”; this signifies that, when they were found to be impaired in the 2002 assessment, TMDLs would be due by 2010.

Troublesome Creek (VAC-H21R-05) was listed for the first time on the *2004 305(b)/303(d) Water Quality Assessment Integrated Report.* The impaired segment is 0.95 miles long, from the Troublesome Creek reservoir dam to the mouth at the Slate River. The segment did not supporting for recreational use due to fecal coliform violations in 2 of 9 samples taken at VADEQ monitoring station 2-TBM000.80. The segment remained on the *2006 305(b)/303(d) Water Quality Assessment Integrated Report* due to fecal coliform violations in 1 of 1 sampling events at VADEQ monitoring station 2-TBM000.80.

Table 1.1 lists, for each impairment, the VADEQ water quality monitoring station(s) used for impaired waters assessment, the initial year that the segment was listed in the Section 303(d) list, current miles affected in the 2004 listing, location information, and the fecal coliform violation rates cited in Virginia’s *2002 Section 303(d) Report on Impaired Waters* and *2004 305(b)/303(d) Water Quality Assessment Integrated Report*.

Table 1.1 Fecal coliform impairments on *2004 305(b)/303(d) Water Quality Assessment Integrated Report* in the James River Tributaries in Albemarle and Buckingham Counties.

Stream Name, HUP	Initial Listing	Listing Station ID(s)	2002 303(d) List FC Violation Rate	2004 303(d) List FC Violation Rate	2006 303(d) List FC Violation Rate	Current Miles Affected	Location from 2004 List
Austin Creek, H21R-01	2004	2-AUS001.12	N/A	3/9	1/1	6.14	Headwaters to the confluence with North River
Ballinger Creek, H17R-03	2004	2-BLR003.00	N/A	3/13	2/6	9.82	Headwaters to the confluence with James River
Frisby Branch, H21R-02	2002	2-FRY000.35 2-FRY003.00	2/6 N/A	2/8 4/9	1/1	3.93	Headwaters to the confluence with Grease Creek
North River, H21R-03	2002	2-NTH001.65 2-NTH003.88	5/21 N/A	5/36 7/9	3/20 1/1	8.44	From confluence with Meadow Creek to the confluence with Slate River
Rock Island Creek, H17R-04	2004	2-RKI003.40	N/A	3/19	2/7	8.84	Headwaters to the confluence with James River
Slate River, H21R-04	2002	2-SLT024.72 2-SLT030.19	3/10 N/A	3/9 5/9	1/1 1/1	13.28	From confluence with Grease Creek to the confluence with Walton Fork
Slate River, H22R-01	2002	2-SLT003.68	4/26	4/27	4/26	7.12	From confluence with Sharps Creek to the confluence with James River
Totier Creek, H17R-01	2002	2-TOT002.61	7/57	13/49	8/34	11.29	Headwaters to the confluence with James River
Troublesome Creek, H21	2004	2-TBM000.80	N/A	2/9	1/1	0.95	From the Troublesome Creek reservoir dam to the mouth at the Slate River

2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Applicable Water Quality Standards

According to 9 VAC 25-260-5 of Virginia's State Water Control Board *Water Quality Standards*, the term 'water quality standards' means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act."

As stated in Virginia state law 9 VAC 25-260-10 (Designation of uses),

> *A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*
>
> ♦
>
> *D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

Section 9 VAC 25-260-170 is the applicable water quality criteria for fecal coliform impairments in the James River Tributaries in Albemarle and Buckingham Counties and reads as follows:

> *A. In surface waters, except shellfish waters and certain waters identified in subsection B of this section, the following criteria shall apply to protect primary contact recreational uses:*
>
> *1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.*

2. E. coli and enterococci bacteria per 100 ml of water shall not exceed the following:

	Geometric Mean[1]	*Single Sample Maximum*[2]
Freshwater[3]		
E. coli	*126*	*235*
Saltwater and Transition Zone[3]		
enterococci	*35*	*104*

[1] For two or more samples taken during any calendar month.
[2] No single sample maximum for *enterococci* and *E. coli* shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater and 0.7 shall be as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.
[3] See 9 VAC 25-260-140 C for freshwater and transition zone delineation.

2.2 Selection of a TMDL Endpoint.

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the James River Tributaries in Albemarle and Buckingham Counties' TMDLs, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations (Table 2.1). In order to remove a waterbody from a state's list of impaired waters, the CWA requires compliance with that state's water quality standard. Since modeling provided simulated output of *E. coli* concentrations at one-hour intervals, assessment of TMDLs was made using both the geometric mean standard of 126 cfu/100 ml and the instantaneous standard of 235 cfu/100 ml. Therefore, the in-stream *E. coli* targets for these TMDLs were a monthly geometric mean not exceeding 126 cfu/100 ml and a single sample not exceeding 235 cfu/100 ml.

Table 2.1 TMDL endpoints for the impairments in the James River Tributaries in Albemarle and Buckingham Counties.

Stream Name	TMDL Endpoint	*E. coli* geometric mean standard	*E. coli* instantaneous standard
Austin Creek	*E. coli*	*126*	*235*
Ballinger Creek	*E. coli*	*126*	*235*
Frisby Branch	*E. coli*	*126*	*235*
North River	*E. coli*	*126*	*235*
Rock Island Creek	*E. coli*	*126*	*235*
Slate River (H21)	*E. coli*	*126*	*235*
Slate River (H22)	*E. coli*	*126*	*235*
Troublesome Creek	*E. coli*	*126*	*235*
Totier Creek	*E. coli*	*126*	*235*

2.3 Selection of a TMDL Critical Condition.

EPA regulations at 40 CFR 130.7 (c)(1) require that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the James River Tributaries in Albemarle and Buckingham Counties is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken in order to meet water quality standards. Fecal bacteria sources within the James River Tributaries in Albemarle and Buckingham Counties are attributed to both point and non-point sources. Critical conditions for waters impacted by land-based non-point sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context, also include non-point sources that are not precipitation driven (*e.g.*, fecal deposition to stream).

A graphical analysis of fecal coliform concentrations and flow duration intervals showed that there was no obvious critical flow level. A description of the data used in this analysis is shown in Table 2.2 and graphical representation of the concentration versus flow for all stations can be found in Appendix D. The analysis showed no obvious dominance of either non-point sources or point sources. High concentrations were recorded in all flow regimes at monitoring stations where data were collected during all flow regimes. Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons (Section 4.5) in order to capture a wide range of hydrologic circumstances for all impaired streams in this study area. The resulting periods for calibration and validation for each impaired stream are presented in Chapter 4.

2.4 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal coliform monitoring data throughout the watershed area of the James River Tributaries in Albemarle and Buckingham Counties. An examination of data from water quality stations used in the 303(d) assessment was performed and data collected during TMDL development were analyzed. Sources of data and pertinent results are discussed.

2.4.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- Bacteria enumerations from 16 VADEQ in-stream monitoring stations used for TMDL assessment (Figure 2.1); and
- Bacteria enumerations and bacterial source tracking from 11 VADEQ in-stream monitoring stations analyzed during TMDL development (Figure 2.2).

2.4.1.1 Water Quality Monitoring for TMDL Assessment

Data from in-stream fecal coliform samples collected by VADEQ were analyzed from January 1990 through January 2006 and are included in the analysis (Table 2.2). Samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting concentrations to 400 cfu/100 mL or less. As a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 mL or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) were not analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported values of 100 cfu/100 mL most likely represent concentrations below 100 cfu/100 mL, and reported concentrations of 8,000 or 16,000 cfu/100 mL most likely represent concentrations in excess of these values. *E. coli* samples were collected from March 2003 through January 2006 to evaluate compliance with the state's current bacterial standard, as well as for bacterial source tracking analysis. Tables 2.2 and 2.3 summarize the fecal coliform and *E. coli* samples collected at the in-stream monitoring stations in the impaired watersheds.

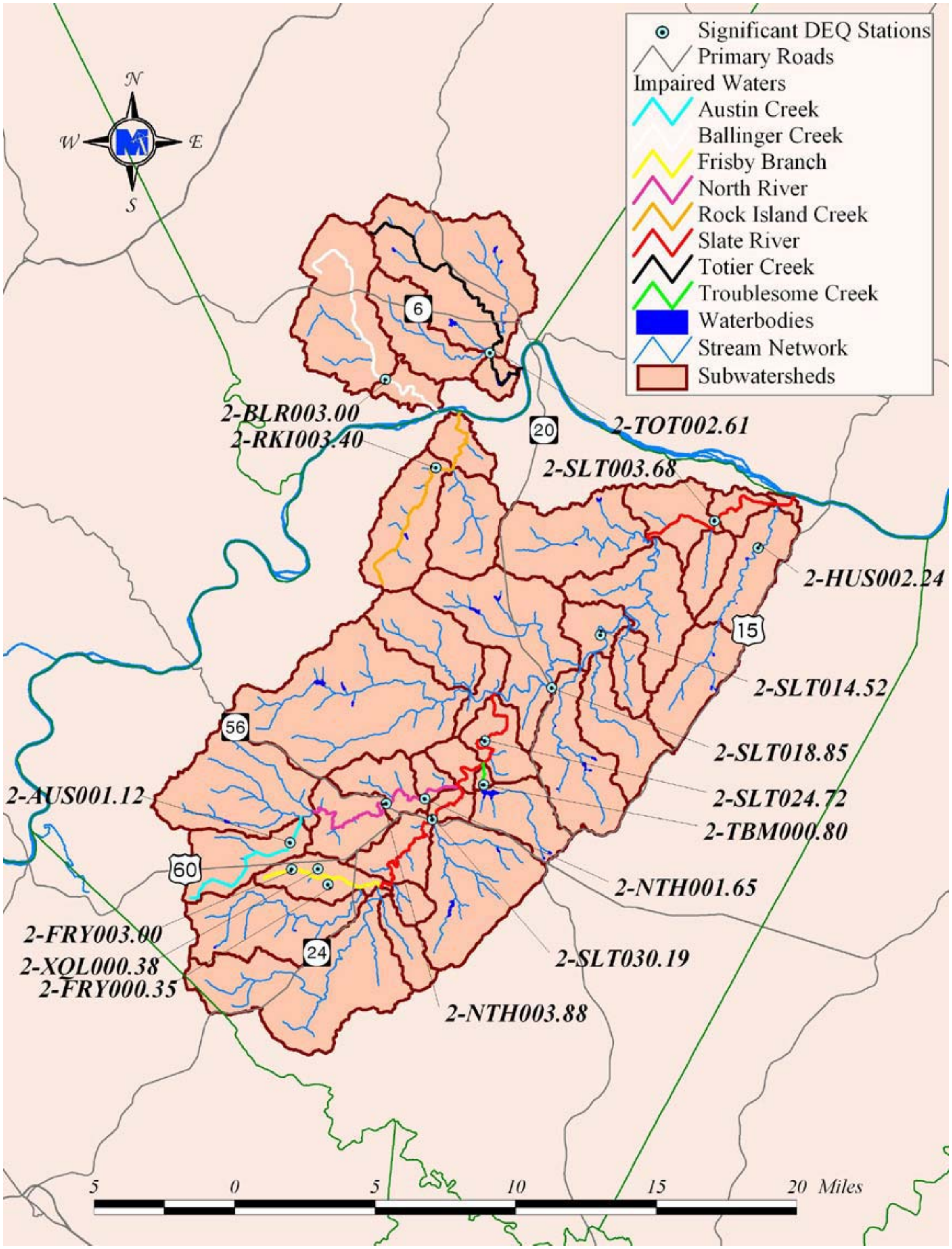

Figure 2.1 Location of VADEQ water quality monitoring stations used for TMDL assessment in the James River Tributaries in Albemarle and Buckingham Counties.

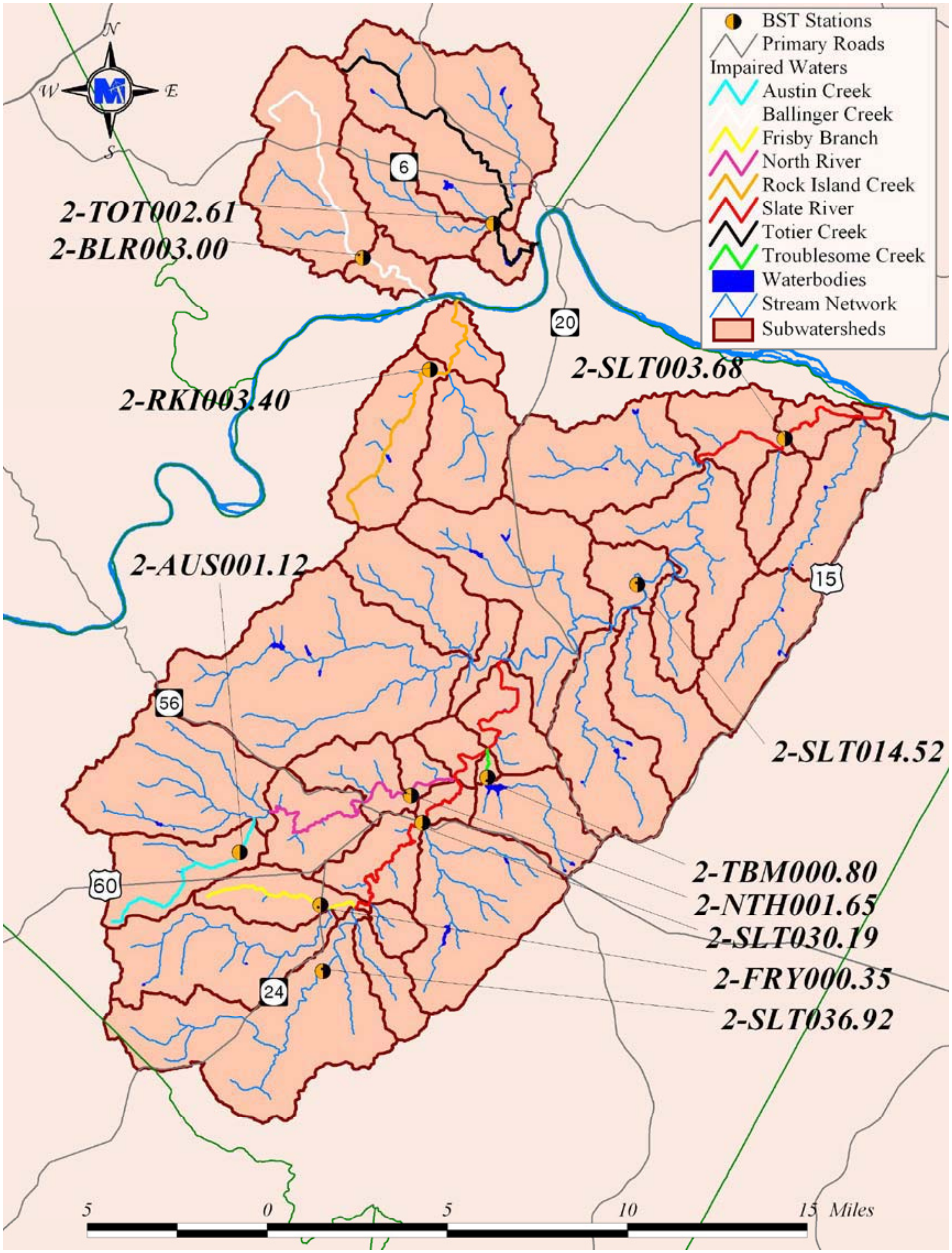

Figure 2.2 Location of BST water quality monitoring stations in the James River Tributaries in Albemarle and Buckingham Counties.

Table 2.2 Summary of fecal coliform (cfu/100 mL) sampling conducted by VADEQ for the period January 1990 through January 2006.

Stream	VADEQ Station	Sample Dates	Count (#)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Mean (cfu/100mL)	Median (cfu/100mL)	Violations[1] %
Austin Creek	2-AUS001.12	10/97 - 4/00	10	15	1,300	275	92	20
Ballinger Creek	2-BLR003.00	8/91 - 6/01	23	100	2,500	443	200	35
Frisby Branch	2-FRY000.35	10/97 - 4/00	9	45	5,400	981	140	22
Frisby Branch	2-FRY003.00	10/97 - 4/00	10	45	5,400	1,103	130	40
Frisby Branch X-Trib	2-XQL000.38	4/99 - 4/00	3	45	490	193	45	33
Hunts Creek	2-HUS002.24	7/05 – 12/05	3	25	25	25	25	0
North River	2-NTH001.65	9/94 - 6/03	49	18	9,200	870	220	24
North River	2-NTH003.88	10/97 - 4/00	10	130	5,400	1,490	1195	70
Rock Island Creek	2-RKI003.40	1/90 - 9/05	53	18	16,000	608	200	21
Slate River	2-SLT003.68	1/90 - 1/06	77	18	5,700	468	100	12
Slate River	2-SLT014.52	11/03 – 3/04	2	25	25	25	25	0
Slate River	2-SLT018.85	9/03 – 3/04	2	25	25	25	25	0
Slate River	2-SLT024.72	10/97 - 4/00	10	45	16,000	2,692	215	30
Slate River	2-SLT030.19	10/97 - 4/00	10	78	9,200	1,732	395	50
Troublesome Creek	2-TBM000.80	10/97 - 4/00	10	18	16,000	1,744	89	20
Totier Creek	2-TOT002.61	8/94 - 12/05	107	25	8,000	605	200	25

[1] Violations are based on the current fecal coliform instantaneous standard (400 cfu/100mL).

Table 2.3 Summary of *E. coli* (cfu/100 mL) sampling conducted by VADEQ for the period March 2003 through January 2006.

Stream	VADEQ Station	Sample Dates	Count (#)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Mean (cfu/100mL)	Median (cfu/100mL)	Violations[1] %
Austin Creek	2-AUS001.12	8/04 - 9/05	12	25	200	52	25	0
Frisby Branch	2-FRY000.35	7/04 - 6/05	12	25	300	85	50	8
Frisby Branch	2-FRY003.00	8/04 - 8/05	12	25	180	76	50	0
Hunts Creek	2-HUS002.24	7/05 – 12/05	3	25	25	25	25	0
North River	2-NTH001.65	7/04 - 6/05	12	25	320	90	50	8
North River	2-NTH003.88	7/04 - 6/05	12	25	550	201	135	33
Rock Island Creek	2-RKI003.40	7/05 – 12/05	6	18	149	66	57	0
Slate River	2-SLT003.68	7/03 - 1/06	17	17.5	720	100.6	30	12
Slate River	2-SLT014.52	7/03 - 5/05	12	25	400	111	38	17
Slate River	2-SLT018.85	7/03 – 12/05	17	25	480	128	75	18
Slate River	2-SLT024.72	7/04 – 6/05	12	25	200	95	75	0
Slate River	2-SLT030.19	7/04 – 6/05	12	25	200	64	50	0
Troublesome Creek	2-TBM000.80	8/04 - 6/05	11	25	500	73	25	9
Totier Creek	2-TOT002.61	7/04 - 12/05	18	25	460	184.2	181	28

[1] Violations are based on the current *E. coli* instantaneous standard (235 cfu/100mL).

2.4.1.2 Water Quality Monitoring Conducted During TMDL Development

Ambient water quality monitoring was performed from July 2005 through June 2006. Specifically, water quality samples were taken at 11 sites throughout the Study Area. Samples were analyzed for *E. coli* and fecal coliform. These sites were also analyzed for bacteria source (*i.e.*, human, livestock, pet, wildlife) by the Environmental Diagnostics Laboratory (EDL) at MapTech, Inc. Tables 2.4 and 2.5 summarize the fecal coliform and *E. coli* concentration data, respectively, at the ambient stations. Bacterial Source Tracking (BST) results are presented and discussed in greater detail in Section 2.4.2.1.

Table 2.4 Summary of *E. coli* (cfu/100 ml) sampling conducted by VADEQ during TMDL development (July 2005 – June 2006).

Impairment	Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Violations[1] (%)
Austin Creek	2AUS001.12	10	8	104	53	46	0
Ballinger Creek	2BLR003.00	12	76	200,000	16,824	154	25
Frisby Branch	2FRY000.35	1	84	84	NA	NA	0
North River	2NTH001.65	10	14	183	67	57	0
Rock Island Creek	2RKI003.40	12	6	1,480	171	56	8
Slate River	2SLT003.68	11	16	86	44	30	0
Slate River	2SLT014.52	11	32	149	62	48	0
Slate River	2SLT030.19	10	26	300	106	73	10
Slate River	2SLT036.92	10	4	134	48	43	0
Troublesome Creek	2TBM000.80	11	2	102	27	16	0
Totier Creek	2TOT002.61	12	60	460	206	198	25

[1]Violations based on new fecal coliform instantaneous standard (*i.e.*, 235 cfu/100mL).

Table 2.5 Summary of fecal coliform (cfu/100 ml) sampling conducted by VADEQ during TMDL development (July 2005 – June 2006).

Impairment	Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Violations[1] (%)
Austin Creek	2AUS001.12	3	100	310	197	180	0
Ballinger Creek	2BLR003.00	3	360	500	417	390	33
Frisby Branch	2FRY000.35	1	240	240	NA	NA	0
North River	2NTH001.65	3	20	90	53	50	0
Rock Island Creek	2RKI003.40	3	70	310	187	180	0
Slate River	2SLT003.68	3	60	140	93	80	0
Slate River	2SLT014.52	3	30	130	90	110	0
Slate River	2SLT030.19	3	90	250	187	220	0
Slate River	2SLT036.92	3	70	200	127	110	0
Troublesome Creek	2TBM000.80	3	1	240	120	120	0
Totier Creek	2TOT002.61	12	40	420	173	150	8

[1]Violations based on new fecal coliform instantaneous standard (*i.e.*, 400 cfu/100mL).

2.4.2 Trend and Seasonal Analyses

Trend and seasonal analyses were performed on precipitation, discharge, and fecal coliform concentrations. No trends were found for flow, precipitation and fecal coliform concentrations. Data tables can be found in Appendix A.

2.4.3 Analysis of BST Data

The data collected were analyzed for frequency of violations, patterns in fecal source identification, and seasonal impacts. Data tables can be found in Appendix B.

2.4.3.1 Bacterial Source Tracking

MapTech, Inc. was contracted to perform BST as well as an analysis of fecal coliform and *E. coli* concentrations. BST is intended to aid in identifying sources (*i.e.,* human, pets, livestock, or wildlife) of fecal contamination in water bodies. Data collected provided insight into the likely sources of fecal contamination, aided in distributing fecal loads from different sources during model calibration, and will improve the chances for success in implementing solutions.

Several procedures are currently under study for use in BST. Virginia has adopted the Antibiotic Resistance Analysis (ARA) methodology implemented by MapTech's EDL. This method was selected because it has been demonstrated to be a reliable procedure for confirming the presence or absence of human, pet, livestock and wildlife sources in watersheds in Virginia. The results were reported as the percentage of isolates acquired from the sample that were identified as originating from either humans, pets, livestock, or wildlife.

The BST results of water samples collected at eleven ambient stations in the James River Tributaries in Albemarle and Buckingham Counties' drainage area are reported in Appendix A. All sources were identified as present in each watershed. The majority of the results were below the water quality standard. The *E. coli* enumerations are given to indicate the bacteria concentrations at the time of sampling. The proportions reported are formatted to indicate statistical significance (*i.e.*, **BOLD** numbers indicate a statistically significant result). The statistical significance was determined through two tests. The first was based on the sample size. A z-test was used to determine if the proportion was significantly different from zero (alpha = 0.10). Second, the rate of false positives was calculated for each source category in each library, and a proportion was not considered significantly different from zero unless it was greater than the false-positive rate plus three standard deviations.

Table 2.6 summarizes the results for each station with load-weighted average proportions of bacteria originating from the four source categories. The load-weighted average considers the level of flow in the stream at the time of sampling, the concentration of *E. coli* measured, and the number of bacterial isolates analyzed in the BST analysis.

Table 2.6 Load-weighted average proportions of fecal bacteria originating from wildlife, human, livestock, and pet sources.

Station ID	Weighted Averages: Wildlife	Human	Livestock	Pet
2AUS001.12	15%	27%	30%	28%
2BLR003.00	36%	11%	30%	22%
2FRY000.35	12%	12%	55%	21%
2NTH001.65	21%	19%	22%	39%
2RKI003.40	57%	25%	8%	9%
2SLT003.68	37%	20%	11%	33%
2SLT014.52	26%	24%	14%	36%
2SLT030.19	21%	9%	44%	25%
2SLT036.92	17%	23%	24%	36%
2TBM000.80	16%	21%	41%	23%
2TOT002.61	26%	8%	43%	24%

2.4.3.2 Fecal Coliform Concentrations

Water quality monitoring data collected by VADEQ were described in section 2.2.1.1. A trend analysis was conducted on data, if sufficient, collected at stations used in TMDL assessment. Totier Creek monitoring station 2-TOT002.61 had a statistically significant downward trend in fecal coliform concentrations between August 1994 and December 2005, Table A.4.

There was insufficient data to perform Mood's Median seasonality tests at any of the monitoring stations.

2.4.4 Summary of In-stream Water Quality Monitoring Data

Wide ranges of fecal coliform concentrations have been recorded in the watershed. Concentrations reported during TMDL development were within the range of historical values reported by VADEQ during TMDL assessment. Exceedances of the instantaneous standard were reported in all flow regimes, leaving no apparent relationship between flow and water quality.

3. SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal coliform in the James River Tributaries in Albemarle and Buckingham Counties. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local management agencies. This section documents the available information and interpretation for the analysis. The source assessment chapter is organized into point and nonpoint sections. The representation of the following sources in the model is discussed in Chapter 4.

3.1 Watershed Characterization

For the period from 1948 to 2005, the area near Bremo Bluff, Virginia (station # 440993) received average annual precipitation of approximately 40.9 inches, with 54% of the precipitation occurring during the May through October growing season (SERCC, 2006). Average annual snowfall is 1.5 inches, with the highest snowfall occurring during February (SERCC, 2006). Average annual daily temperature is 55.8 ºF. The highest average daily temperature of 89.3 ºF occurs in July, while the lowest average daily temperature of 22.6 ºF occurs in January (SERCC, 2006).

The National Land Cover Data (NLCD) produced cooperatively between the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (EPA) was utilized for this study. The collaborative effort to produce this dataset is part of a Multi-Resolution Land Characteristics (MRLC) Consortium project led by four U.S. government agencies: EPA, USGS, the Department of the Interior National Biological Service (NBS), and the National Oceanic and Atmospheric Administration (NOAA). Using 30-meter resolution Landsat 5 Thematic Mapper (TM) satellite images taken between 1990 and 1994, digital land use coverage was developed identifying up to 21 possible land use types. Classification, interpretation, and verification of the land cover dataset involved several data sources when available, including: aerial photography; soils data; population and housing density data; state or regional land cover data sets; USGS land use and land cover (LUDA) data; 3-arc second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief; and National Wetlands Inventory (NWI) data. In addition MapTech developed an additional land use from the pasture category called "Livestock Access". The acreage for this land use was developed by determining a 35 foot buffer around perennial streams that bordered pasture. Approximate acreages and land use proportions for each impaired segment are given in Table 3.1 and shown in Figure 3.1.

Table 3.1 Contributing land use area for impaired segments in the James River Tributaries in Albemarle and Buckingham Counties.

Impaired Segment	Land use								
	Barren (acres)	Commercial (acres)	Forest (acres)	Livestock Access (acres)	Residential (acres)	Pasture (acres)	Cropland (acres)	Water (acres)	Wetlands (acres)
Austin Creek	544	0	3,976	0	10	56	13	19	119
Ballinger Creek	68	0.22	8,077	116	109	2,494	182	87	53
Frisby Branch	181	0	2,718	4	4	199	28	14	41
North River	1,248	0	17,974	52	21	2,058	158	136	501
Rock Island Creek	552	0.25	11,410	15	74	683	74	88	150
Slate River Lower	7,596	109	129,311	352	728	14,163	1,152	1,503	2,026
Slate River Upper	3,218	67	57,198	117	284	5,945	525	607	1,249
Totier Creek	321	7	10,794	217	198	6,804	479	261	200
Troublesome Creek	224	36	3,286	9	101	470	43	97	37
Total	13,952	219.47	244,744	882	1,529	32,872	2,654	2,812	4,376

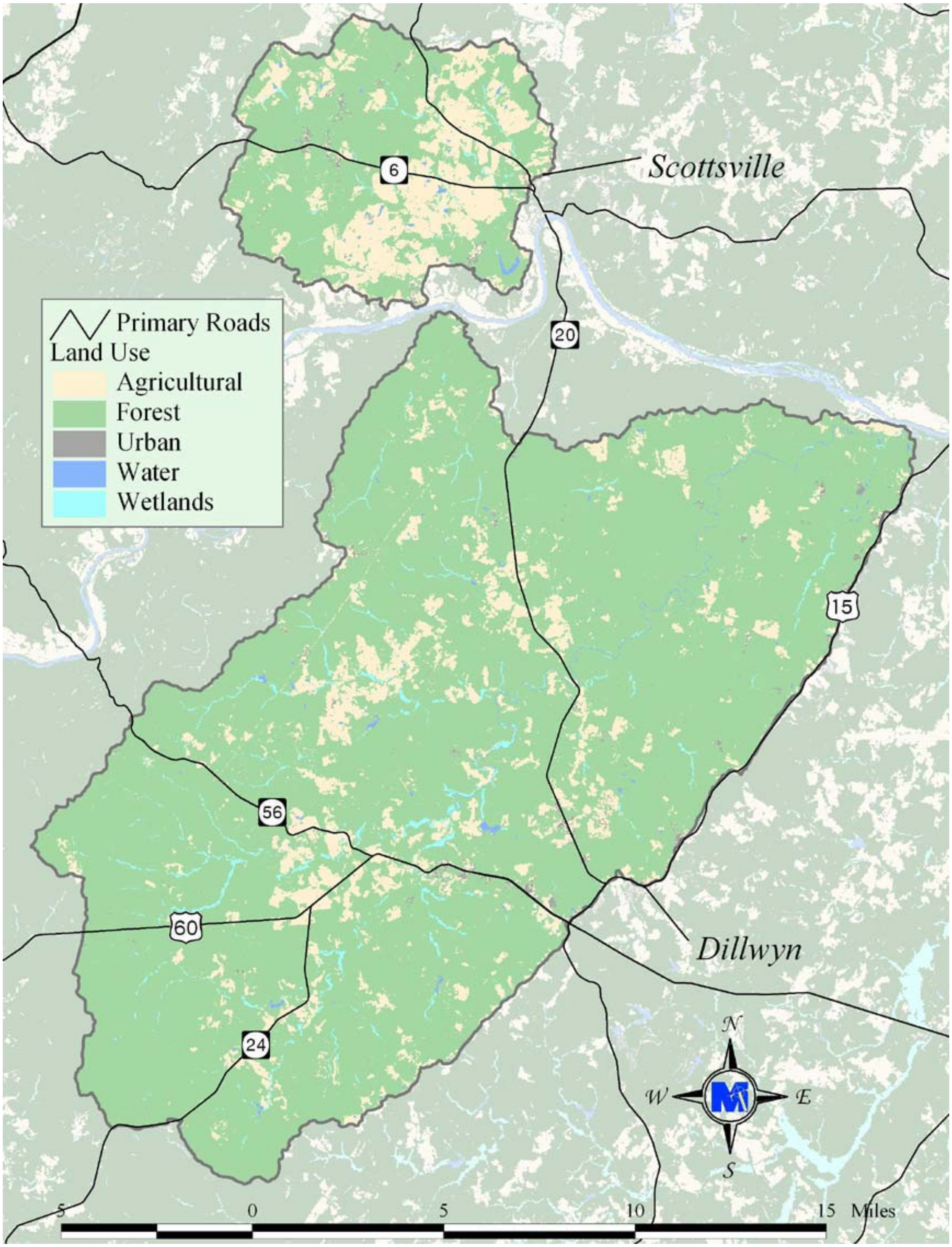

Figure 3.1 Land uses in the watershed of the James River Tributaries in Albemarle and Buckingham Counties.

The estimated human population within the impaired drainage areas in 2006 is 11,008, with 2,182 dogs and 2,443 cats associated with this population. Table 3.2 lists agricultural production rankings for Albemarle and Buckingham Counties compared to all counties in Virginia (VASS, 2003; NASS, 2002a; NASS, 2002b). Albemarle and Buckingham Counties are home to numerous species of wildlife, including mammals (*e.g.,* muskrat, beaver, raccoon, white-tailed deer) and birds (*e.g.,* wood duck, wild turkey, Canada goose) (VDGIF, 2004) (Table 3.3).

Table 3.2 Agricultural production rankings for Albemarle and Buckingham Counties compared to all counties in Virginia.

County	County Rankings Compared to Other Counties in Virginia						
	Cattle & Calves*	Sheep*	Beef*	Horses[1]	Layers	Broilers	Swine[2]
Albemarle	21	11	17	3	NA	NA	33
Buckingham	32	NA	26	NA	3	9	2

*VASS, 2003. [1] NASS, 2002a. [2] NASS, 2002b, NA figure not available

Table 3.3 Number of wildlife species, mammal types, and bird types inhabiting Albemarle and Buckingham Counties*.

County / City	Number of Wildlife Species	Number of Mammal Types	Number of Bird Types
Albemarle	428	47	193
Buckingham	358	42	161

*VDGIF, 2004.

3.2 Assessment of Point Sources

Six point sources are permitted in the watershed of the James River Tributaries in Albemarle and Buckingham Counties through the Virginia Pollutant Discharge Elimination System (VPDES). Five of the six point sources are permitted in Buckingham County, and one is in Albemarle County (Table 3.4). Figure 3.2 shows the permitted locations. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain a fecal coliform concentration below 200 cfu/100 ml. Currently, these permitted discharges are expected not to exceed the 126 cfu/100ml *E. coli* standard. One method for achieving this goal is chlorination. Chlorine is added during the treatment process (and then removed prior to discharge) at levels intended to kill off any pathogens. The monitoring method for ensuring the goal is to measure the concentration of total residual chlorine (TRC) in the effluent. If the concentration is high enough, pathogen concentrations (including fecal coliform concentrations) are considered reduced to acceptable levels. Typically, if minimum TRC levels are met, bacteria concentrations are reduced to levels well below the standard.

Table 3.5 summarizes data from VPDES Confined Animal Feeding Operations (CAFO) and from Virginia Pollution Abatement (VPA) facilities along with the streams that receive potential runoff from these facilities. Figure 3.3 shows the VPA and CAFO locations. These eight permitted sources do not have direct discharges to waterways but runoff from the area could contain fecal coliform and *E. coli* bacteria.

Table 3.4 Summary of VPDES permitted point sources in the James River Tributaries in Albemarle and Buckingham Counties.

Permit	Facility	Receiving Stream	Flow (MGD)	Permitted For Fecal	Data Availability
VA0063291	Sprouses Motel	UT Troublesome Creek	0.005	Y	4/99 – 2/06
VA0066460	DOC - Buckingham Correctional Center	Turpin Creek	0.3	Y	4/99 – 2/06
VA0087653	Sprouses Trailer Park	UT to Bryant Creek	0.0032	Y	4/99 – 12/02
VA0058050	Buckingham County WTP	Troublesome Creek	NA	N	4/99 – 2/06
VA0091685	Kyanite Mining Corporation Mullite Plant	UT, to Gold Mine Branch	NA	N	NA
VA0055018	Scottsville WTP	Totier Creek	0.068	N	11/98 – 7/06
VAG404041	Private Residence	Ripley Creek UT	0.0004	Y	None
VAG404116	Private Residence	Ripley Creek UT	0.001	Y	None
VAG404166	Baptist Union Baptist Church	Hunts Creek UT	0.001	Y	None
VAG407204	Private Residence	UT to Sharps Creek	0.0005	Y	None
VAG407237	Private Residence	Slate River UT	0.0009	Y	None

NA: Industrial facilities, there is no permitted flow.

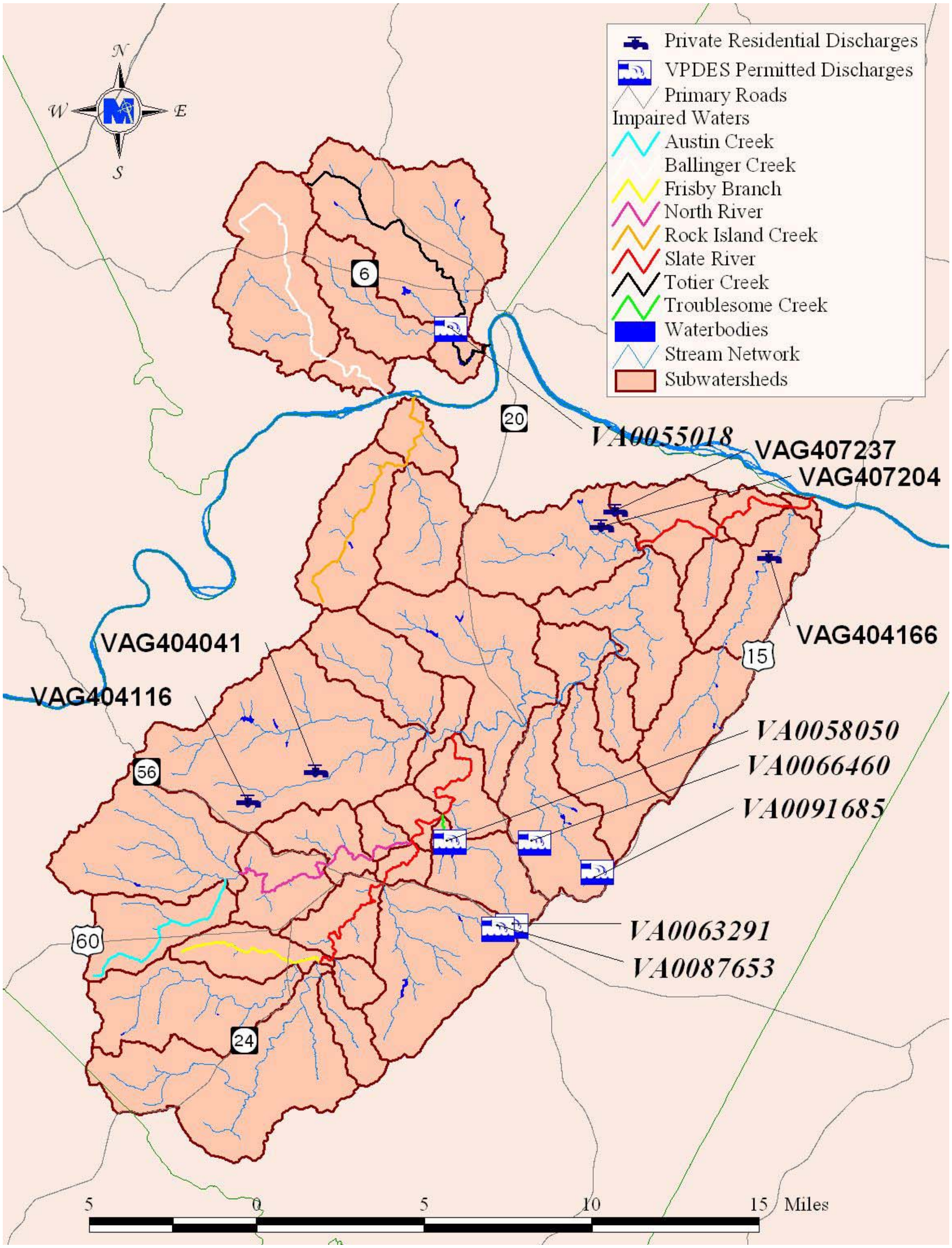

Figure 3.2 Location of VPDES permitted point sources in the James River Tributaries in Albemarle and Buckingham Counties.

Table 3.5 Summary of VPA and CAFO permits in the James River Tributaries in Albemarle and Buckingham Counties.

Watershed	Facility Name	Permit No	Facility Type	Permitted For Fecal Control	Data Availability
Frisby Branch	Heath Farm	VPG100040	CAFO	No	ND
Lower Slate River	Oreatha Eldridge	VPG270046	Poultry	No	ND
Lower Slate River	Thomas A. Newton Sr.	VPG270044	Poultry	No	ND
Lower Slate River	Wilmoth Brothers Farm	VPG100047	CAFO	No	ND
North River	Davis Farm	VPG100038	CAFO	No	ND
North River	Tammy Price	VPG270031	Poultry	No	ND
Troublesome Creek	Daniel Lester Farm	VPG270041	Poultry	No	ND
Troublesome Creek	Huskey and Son Farm	VPG100025	CAFO	No	ND

ND – no data, facility not required to submit monitoring data.

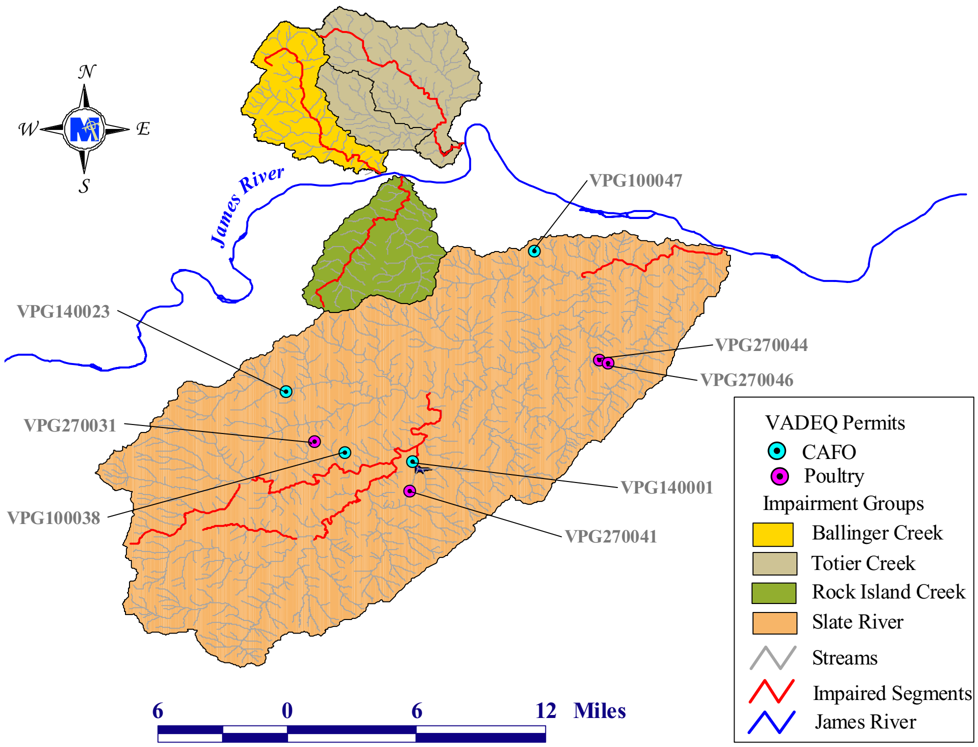

Figure 3.3 Location of VPA and CAFO permitted point sources in the James River Tributaries in Albemarle and Buckingham Counties.

3.3 Assessment of Nonpoint Sources

In the watershed of the James River Tributaries in Albemarle and Buckingham Counties, both urban and rural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage treatment systems, land application of waste (livestock and biosolids), livestock, wildlife, and pets. Sources were identified and enumerated. MapTech collected samples of fecal coliform sources (*i.e.,* wildlife, livestock, pets, and human waste) and enumerated the density of fecal coliform bacteria to support the modeling process and to expand the database of known fecal coliform sources for purposes of bacterial source tracking (Section 2.4.2.1). Where appropriate, spatial distribution of sources was also determined.

3.3.1 Private Residential Sewage Treatment

In the U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank or a cesspool, or the sewage is disposed of in some other way. The Census category "Other Means" includes the houses that dispose of sewage other than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewage via a pit-privy or through the use of a straight pipe (direct stream outfall). Population, housing units, and type of sewage treatment from U.S. Census Bureau data were calculated using GIS (Table 3.6). Census data from 1990 and 2000 were used to project forward to the year 2006.

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant.

When the flow of wastewater exceeds the design capacity, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows. Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system.

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal coliform is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems contribute virtually no fecal coliform to surface waters.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation, the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to proximity. A survey of septic pump-out contractors performed by MapTech showed that failures were more likely to occur in the winter-spring months than in the summer-fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed in the yard.

MapTech sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml (MapTech, 2001). An average fecal coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

Table 3.6 Human population, housing units, houses on sanitary sewer, septic systems, and other sewage disposal systems for 2006 in areas contributing to impaired segments in the James River Tributaries in Albemarle and Buckingham Counties.

Impaired Segment	Population	Housing Units	Sanitary Sewer	Septic Systems	Other **
Totier Creek	1,216	505	0	467	18
Ballinger Creek	748	271	0	256	12
Rock Island Creek	795	330	0	312	15
Lower Slate River	8,249	2,980	226	2,561	193
Upper Slate River	2,789	1,248	105	969	69
North River	601	264	20	229	16
Troublesome Creek	490	234	46	175	14
Austin Creek	91	36	0	34	2
Frisby Creek	199	72	0	68	4
Total*	**11,008**	**4,086**	**226**	**3,596**	**238**

*Total columns do not add up due to nested impairments. To confirm the totals add the Totier Creek, Ballinger Creek, Rock Island Creek and Lower Slate River impairments.

** Houses with sewage disposal systems other than sanitary sewer and septic systems.

3.3.2 Biosolids

Biosolids were applied to 1,085 acres of farmland in Buckingham County by two different companies in 2002. The total amount of Biosolids applied was 5,274 dry tons. The application of biosolids to agricultural lands is strictly regulated in Virginia (VDH, 1997). Biosolids are required to be spread according to sound agronomic requirements with consideration for topography and hydrology. Class B biosolids may not have a fecal coliform density greater than 1,995,262 cfu/g (total solids). Application rates must be limited to a maximum of 15 dry tons/acre per three-year period. Considerable amounts of biosolids were applied in the year 2002, where Rock Island Creek impairment received about 71 dry tons, Upper Slate River impairment received about 2,885 dry tons, and lower Slate River impairment received about 6,454 dry tons.

3.3.3 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the James River Tributaries in Albemarle and Buckingham Counties and were the only pets considered in this analysis. Cat and dog populations by household were derived from 1997 demographics from the American Veterinary Medical Association Center for Information Management. In addition to dogs living in households, there were reports of kennels that house hunting dogs in Buckingham County. Attempts to quantify the number of these types of operations, and their locations were unsuccessful. The large numbers of dogs in these watersheds could be a significant source of fecal coliform; therefore, this should be a consideration during development of implementation plans. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was measured during the Blackwater River TMDL study conducted by MapTech (Fecal Coliform TMDL Development for Upper Blackwater River, VA, 12/2000). Fecal coliform density for dogs and cats was measured from samples collected throughout Virginia by MapTech. A summary of the data collected is given in Table 3.7. Table 3.8 lists the domestic animal populations for impairments in the James River Tributaries in Albemarle and Buckingham Counties.

Table 3.7 Domestic animal population density, waste load, and fecal coliform density.

Type	Population Density (an/house)	Waste load (g/an-day)	FC Density (cfu/g)
Dog	0.534	450	480,000
Cat	0.598	19.4	9

Table 3.8 Estimated domestic animal populations in areas contributing to impaired segments in the James River Tributaries in Albemarle and Buckingham Counties.

Impaired Segment	Dogs	Cats
Austin Creek	19	22
Ballinger Creek	145	162
Frisby Branch	39	43
Lower Slate River	1,591	1,782
Upper Slate River	702	786
North River	141	158
Rock Island Creek	176	197
Totier Creek	270	302
Troublesome Creek	125	140
Ballinger Creek	145	162
Totier Creek	270	302

3.3.4 Livestock

The predominant types of livestock in the watershed area of the James River Tributaries in Albemarle and Buckingham Counties are poultry, beef cattle, and swine, although all types of livestock identified were considered in modeling the watershed. Additionally, as the James River Tributaries in Albemarle and Buckingham Counties encompass a large area, the individual impaired streams in this study have a large diversity in the proportion of contributing livestock species. Operations range from small to large in size, including several operations permitted under either VPA or CAFO regulations. (Table 3.5 provides a summary of these permitted operations in the drainage area of impaired streams in the James River Tributaries in Albemarle and Buckingham Counties.) Table 3.9 gives a summary of livestock populations in Albemarle and Buckingham Counties during the period for source assessment, organized by impairment. Animal populations were based on communication with Virginia Cooperative Extension Service (VCE), Virginia Department of Conservation and Recreation (VADCR), Natural Resources Conservation Service (NRCS), Southside Soil and Water Conservation District (SSWCD), Thomas Jefferson Soil and Water Conservation District (TJSWCD), Peter Francisco Soil and Water Conservation District (PFSWCD), and the Albemarle County Farm Bureau. Note that beef cattle population numbers are based on adult beef only, while the "total cattle" category includes calves as well as adult cattle. Values of fecal coliform density of livestock sources were based on sampling performed by MapTech (MapTech, 1999a). Reported manure production rates for livestock were taken from American Society of Agricultural Engineers (1998). A summary of fecal coliform density values and manure production rates is presented in Table 3.13.

Table 3.9 Livestock populations in areas contributing to impaired segments in the James River Tributaries in Albemarle and Buckingham Counties (1997 – 2006).

Impaired Segment	All cattle	Beef	Dairy	Hog (unconfined)	Horse	Sheep
Austin Creek	27	16	0	1	0	0
Ballinger Creek	557	315	0	3	182	59
Frisby Branch	94	57	0	3	2	0
Lower Slate River	6,870	4,164	0	200	112	209
Upper Slate River	2,416	1,465	0	70	39	7
North River	1,003	608	0	29	16	0
Rock Island Creek	335	203	0	10	5	0
Totier Creek	939	294	0	7	485	156
Troublesome Creek	222	135	0	6	4	3

Table 3.10 Average fecal coliform densities and waste loads associated with livestock.

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)	Fecal Coliform (cfu/day)
Dairy (1,400 lb)	120.4	271,000	14,800,242,240
Beef (800 lb)	46.4	101,000	2,125,751,040
Horse (1,000 lb)	51.0	94,000	2,174,558,400
Swine (135 lb)	11.3	400,000	2,050,272,000
Swine Lagoon	N/A	95,300[1]	N/A
Sheep (60 lb)	2.4	43,000	46,811,520
Goat (140 lb)	5.7	15,000	38,782,800
Dairy Separator	N/A	32,000[1]	N/A
Dairy Storage Pit	N/A	44,600[1]	N/A
Poultry			
Broiler	0.17	586,000	45,187,632
Layer	0.26	586,000	69,110,496

[1]units are cfu/100ml

Fecal coliform produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (*e.g.,* pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Table 3.11 shows the average percentage of collected animal waste that is applied throughout the year. Second, grazing livestock deposit manure directly on the land where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities have drainage systems that divert wash-water and waste directly to drainage ways or streams.

Table 3.11 Average percentage of collected livestock waste applied throughout year.

Month	Applied % of Total				Land use
	Dairy	*Beef*	*Swine*	*Poultry*	
January	1.50	8.33	0.00	0.00	Cropland
February	1.75	8.33	0.00	5.00	Cropland
March	17.00	8.34	20.00	25.00	Cropland
April	17.00	8.34	20.00	20.00	Cropland
May	17.00	8.33	20.00	5.00	Cropland
June	1.75	8.33	0.00	5.00	Pasture
July	1.75	8.33	0.00	5.00	Pasture
August	1.75	8.33	0.00	5.00	Pasture
September	5.00	8.34	0.00	10.00	Cropland
October	17.00	8.34	20.00	10.00	Cropland
November	17.00	8.33	20.00	10.00	Cropland
December	1.50	8.33	0.00	0.00	Cropland

Poultry is one of the major livestock commodities in the watershed area of the James River Tributaries in Albemarle and Buckingham Counties and poultry litter is the primary source of land-applied livestock waste. The transfer of poultry litter for use as a soil amendment is becoming more common within the state of Virginia. The VADEQ maintains records of poultry litter transfers, and a review of these records indicates that significant amounts of litter were transferred into and utilized within Buckingham County in 2004 (the only year records were available). Table 3.12 contains a summary of the poultry litter transfers in this watershed. VADEQ records did not indicate any exports of litter outside of the study area.

Table 3.12 Transfer of poultry litter within the James River Tributaries in Albemarle and Buckingham Counties.

Impaired Watershed	2004 (tons)
Slate River	1,128
Troublesome Creek	160
Walton Fork	90

All livestock were expected to deposit some portion of waste on land areas. The percentage of time spent on pasture for beef cattle was reported by the NRCS, VADCR, and VCE, Table 3.13. Horses, sheep, and goats were assumed to be in pasture 100% of the time.

Based on discussions with local stakeholders, VCE, and NRCS, it was concluded that beef cattle were expected to make a significant contribution through direct deposition to streams in areas where the water flowed freely. In areas with stream fencing BMPs in place, or areas with large amounts of standing or slowly moving water (*i.e.,* swamps), it was concluded that direct deposition was minimal to non-existent. For areas where direct deposition by cattle is assumed, the average amount of time spent by beef cattle in stream access areas (*i.e.*, within 50 feet of the stream) for each month is given in Table 3.13.

Table 3.13 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day.

Month	Pasture (hr)	Stream Access (hr)
January	23.3	0.7
February	23.3	0.7
March	23.0	1.0
April	22.6	1.4
May	22.6	1.4
June	22.3	1.7
July	22.3	1.7
August	22.3	1.7
September	22.6	1.4
October	23.0	1.0
November	23.0	1.0
December	23.3	0.7

3.3.5 Wildlife

The predominant wildlife species in Albemarle and Buckingham counties were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), United States Fish and Wildlife Service (FWS), citizens from the watershed, source sampling, and site visits. Population densities were calculated from data provided by VDGIF and FWS, and are listed in Table 3.14 (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; Raftovich, 2004; Rose and Cranford, 1987). The numbers of animals estimated to be in Albemarle and Buckingham counties are reported in Table 3.15. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996, and Yagow, 1999b). Table 3.16 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife scat performed by MapTech. The only value that was not obtained from MapTech sampling in the watershed was for beaver. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999a). Percentage of time spent in stream access areas and percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.*, within 100 feet of stream) are reported in Table 3.17.

Table 3.14 Wildlife population density.

Deer (an/ac of habitat)	Turkey (an/ac)	Goose (an/ac)	Duck (an/ac)	Muskrat (an/ac of habitat)	Raccoon (an/ac of habitat)	Beaver (an/mi of stream)	Beaver (an/mi along lakes, marshes, rivers)
0.0269	0.0047	0.026	0.0199	0.6518	0.018	2.0	1.6

Table 3.15 Wildlife populations in the James River Tributaries in Albemarle and Buckingham Counties.

Impairment	Deer	Turkey	Goose	Duck	Muskrat	Raccoon	Beaver
Austin Creek	113	22	14	10	340	78	14
Ballinger Creek	296	46	38	29	963	204	30
Frisby Branch	81	15	10	8	256	56	10
North River	562	100	79	60	1,972	401	77
Rock Island Creek	334	61	43	33	1,065	227	38
Slate River_Lower	3,977	710	547	416	13,681	2,784	540
Slate River_Upper	1,838	329	263	199	6,567	1,313	257
Totier Creek	501	67	74	57	1,862	358	61
Troublesome Creek	105	18	21	16	526	85	17

Table 3.16 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	Primary = region within 600 ft of perennial streams Secondary = region between 601 and 7,920 ft from perennial streams Infrequent/Seldom = rest of watershed area including waterbodies (lakes, ponds)
Muskrat	100	Primary = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies Secondary = region between 67 and 308 ft from perennial streams, and waterbodies Infrequent/Seldom = rest of the watershed area
Beaver[1]	200	Primary = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) Infrequent/Seldom = rest of the watershed area
Deer	772	Primary = forested, harvested forest land, orchards, grazed woodland, urban grassland, cropland, pasture, wetlands, transitional land Secondary = low density residential, medium density residential Infrequent/Seldom = remaining land use areas
Turkey[2]	320	Primary = forested, harvested forest land, grazed woodland, orchards, wetlands, transitional land Secondary = cropland, pasture Infrequent/Seldom = remaining land use areas
Goose[3]	225	Primary = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies Secondary = region between 67 and 308 ft from perennial streams, and waterbodies Infrequent/Seldom = rest of the watershed area
Mallard	150	Primary = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies Secondary = region between 67 and 308 ft from perennial streams, and waterbodies Infrequent/Seldom = rest of the watershed area

1 Beaver waste load was calculated as twice that of muskrat, based on field observations.
2 Waste load for domestic turkey (ASAE, 1998).
3 Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2003).

Table 3.17 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	380,000	5
Turkey	1,332	5
Goose	250,000	50
Duck	3,500	75

4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of TMDLs for the James River Tributaries in Albemarle and Buckingham counties, the relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality. In this section, the selection of modeling tools, source assessment, selection of a representative period, calibration/validation, and model application are discussed.

4.1 Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and to perform TMDL allocations in riverine areas. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLND) and pervious land areas (PERLND). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, representing the various land uses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES in that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

4.2 Model Setup

To adequately represent the spatial variation in the watershed, the drainage area of the James River Tributaries in Albemarle and Buckingham counties was divided into 41 subwatersheds for the purpose of modeling hydrology and water quality (Figure 4.1). The rationale for choosing these subwatersheds was based on the availability of water quality data and the limitations of the HSPF model. The HSPF model is constrained by the number of operations that it is capable of representing and, thus, necessitated a division of the watershed model into six distinct linked models. The output from one model was then routed into the next downstream model, where appropriate. Figure 4.1 shows the sub-model linkages, which were used to achieve the unified model. Water quality data (*i.e.,* fecal coliform concentrations) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with these monitoring stations, since output from the model can only be obtained at the modeled subwatershed outlets (Figure 4.1). In an effort to standardize modeling efforts across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watersheds allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watersheds.

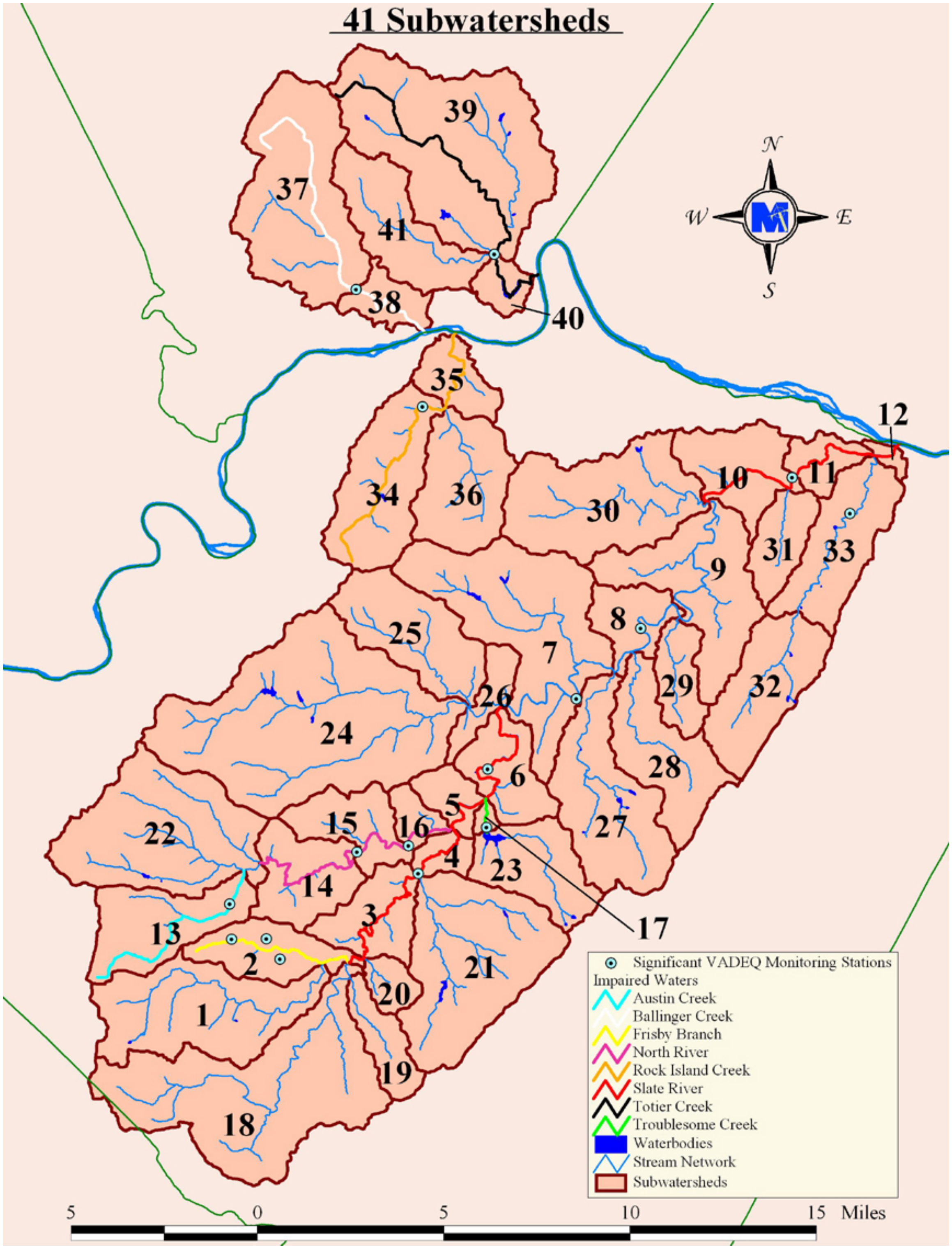

Figure 4.1 Subwatersheds delineated for modeling and location of VADEQ Water Quality Monitoring Stations in the watershed of the James River tributaries in Albemarle and Buckingham counties.

Using aerial photographs, Multi-Resolution Land Characteristics (MRLC) identified 14 land use types in the watersheds. The 14 land use types were consolidated into nine categories based on similarities in hydrologic and waste application/production features (Table 4.1). Within each subwatershed, up to the nine land use types were represented (Table 3.1). Each land use had parameters associated with it that described the hydrology of the area (*e.g.,* average slope length) and the behavior of pollutants (*e.g.,* fecal coliform accumulation rate). These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). Impervious areas in the watershed are represented in three IMPLND types, while there are nine PERLND types, each with parameters describing a particular land use (Table 4.1). Some IMPLND and PERLND parameters (*e.g.,* slope length) vary with the particular subwatershed in which they are located. Others vary with season (*e.g.,* upper zone storage) to account for plant growth, die-off, and removal.

Table 4.1 Consolidation of MRLC land use categories for the James River Tributaries in Albemarle and Buckingham Counties.

TMDL Land use Categories	Pervious/Impervious (Percentage)	MRLC Land use Classifications (Class No.)
Water	Impervious (100%)	Open Water (11)
Residential	Pervious (65%) Impervious (35%)	Low Intensity Residential (21) High Intensity Residential (22) Urban/Recreational Grasses (85)
Commercial and Services	Pervious (60%) Impervious (40%)	Commercial/Industrial/Transportation (23)
Barren	Pervious (80%) Impervious (20%)	Quarries/Strip Mines/Gravel Pits (32) Transitional (33)
Woodland	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)
Pasture	Pervious (100%)	Pasture/Hay (81)
Cropland	Pervious (100%)	Row Crops (82)
Wetlands	Pervious (100%)	Woody Wetlands (91) Emergent Herbaceous Wetlands (92)
Livestock Access	Pervious (100%)	Pasture/Hay (81)

Die-off of fecal coliform can be handled implicitly or explicitly. For land-applied fecal matter (mechanically applied and deposited directly), die-off was addressed implicitly through monitoring and modeling. Samples of collected waste prior to land application (*i.e.,* dairy waste from loafing areas) were collected and analyzed previously by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal coliform entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

4.3 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.,* stream geometry and resistance to flow). These data are entered into HSPF via the Hydraulic Function Tables (F-tables). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and outflow (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume of the flow in the reach, and is reported in acre-feet. The outflow is simply the stream discharge, in cubic feet per second.

In order to develop the entries for the F-tables, a combination of the NRCS Regional Hydraulic Geometry Curves (NRCS, 2006) and Digital Elevation Models (DEM) was used. The NRCS has developed an empirical formula for estimating stream top width, cross-sectional area, average depth, and flow rate, all as functions of the drainage area. Estimates were obtained at the outlet of each subwatershed. Using the NRCS equations, an entry was developed in the F-table that represented a bank-full situation for the streams. However, the F-table is supposed to cover the floodplains. The floodplain information was obtained from the DEM. A profile perpendicular to the channel was generated showing the floodplain height with distance for each subwatershed outlet. An example of this profile is given in Figure 4.2. Consecutive entries to the F-table are generated by estimating the volume of water and surface area in the reach at incremental depths (where depths are taken from the outlet profile, e.g. Figure 4.3).

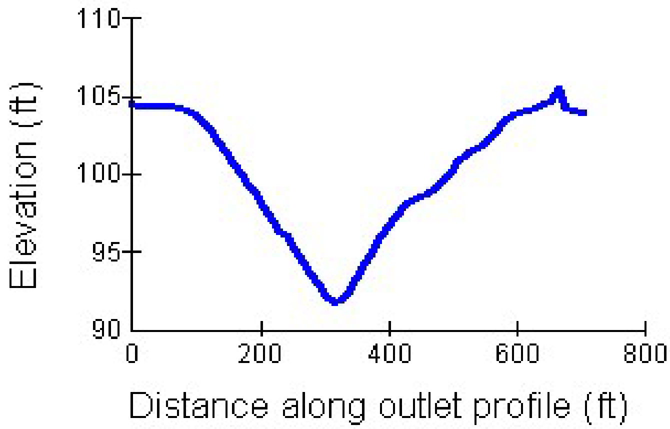

Figure 4.2 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with values for resistance to flow (Manning's *n*) assigned based on recommendations by Brater and King (1976) and shown in Table 4.2. The conveyance was calculated for each of the two flood plains and the main channel; these figures were then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from Digital Elevation Models (DEMs) and a stream-flow network based on National Hydrography Dataset (NHD) Data. The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth. An example of an F-table used in HSPF is shown in Table 4.3.

Table 4.2 Summary of Manning's roughness coefficients for channel cells*.

Section	Upstream Area (ha)	Manning's *n*
Intermittent stream	18 - 360	0.06
Perennial stream	360 and up	0.05

*Brater and King (1976)

Table 4.3 Example of an "F-table" calculated for the HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0	0	0	0
0.1	0.6	1.69	0.05
0.17	10.76	4.46	24.26
0.77	10.76	10.44	241.7
7.67	11.84	82.36	11150.2
9.59	13.64	104.21	16167.77
11.99	35.37	186.7	21029.3
14.39	36.12	270.99	38599.01
246.99	108.79	16985.15	17519166
479.6	181.45	50601.57	76135368

4.4 Selection of Representative Modeling Period

Selection of the modeling period was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station 02030500 in the Slate River near Arvonia was available from 1926 through 1995. The modeling period was selected to include the VADEQ assessment period from July 1990 through December 2002 that led to the inclusion of the impaired streams in this TMDL study area on the 1996, 1998, 2002 and 2004 Section 303(d) lists. The fecal concentration data from this period were evaluated to determine the relationship between concentration and the level of flow in the stream. High concentrations of fecal coliform were recorded in all flow regimes, thus it was concluded that the critical hydrological condition included a wide range of wet and dry seasons.

In order to select a modeling period representative of the critical hydrological condition from the available data, the mean daily flow and precipitation for each season were calculated for the period January 1950 through October 1995. The results of this analysis are shown in Figures 4.4 through 4.5. This resulted in at least 68 observations of flow and precipitation for each season. The mean and variance of these observations were calculated. Next, a candidate period was chosen based on the availability of mean discharge data closest to the fecal coliform assessment period (7/90-1/06). The representative period was chosen from this candidate period such that the mean and variance of each season in the modeled period was not significantly different from the historical data (Table 4.4). Therefore, the period was selected as representing the hydrologic regime of the study area, accounting for critical conditions associated with all potential sources within the watershed. The resulting periods for hydrologic calibration was October 1992 to September 1995. For hydrologic validation, the periods selected were October 1987 to September 1990.

For water quality calibration, data availability was the governing factor in the choice of calibration, validation, and allocation periods. The period containing the greatest amount of monitored data dispersed over the most stations, and for which the assessment of potential sources was most accurate (10/1/1996 to 9/30/1999), was chosen as the calibration period. This period contained 115 water quality data points spread over seven stations. The period from 10/1/1999 to 9/30/2001 was chosen as the validation period, with 43 data points over seven water quality sampling stations. The representative hydrological period was chosen as the allocation period to ensure that the critical conditions in the watershed were being simulated during water quality allocations.

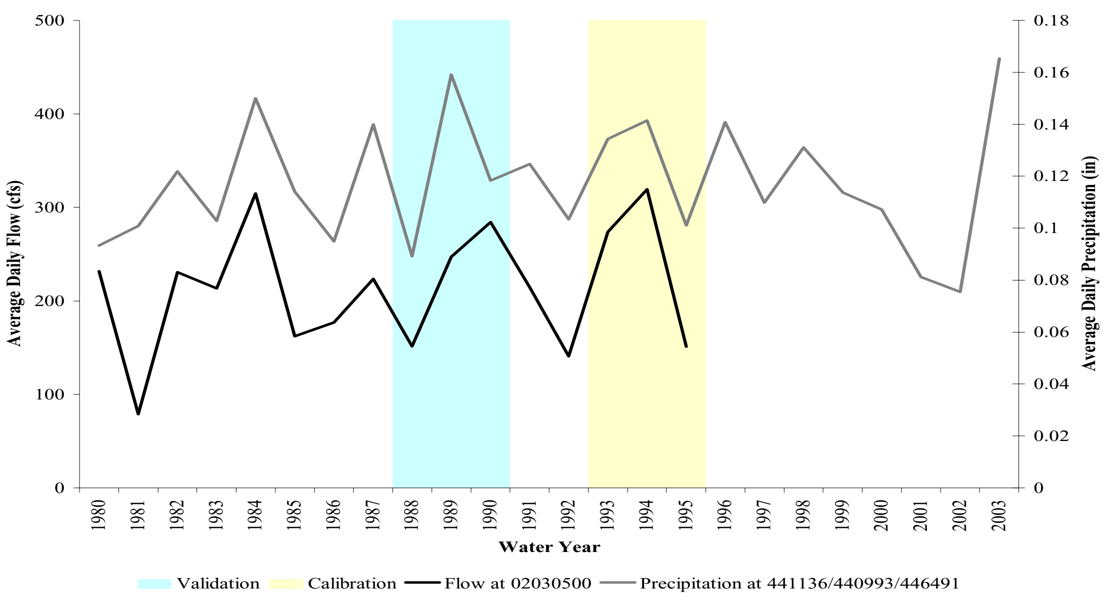

Figure 4.3 Annual Historical Flow (USGS Station 02030500) and Precipitation (Stations 441136, 440993, 446491) Data

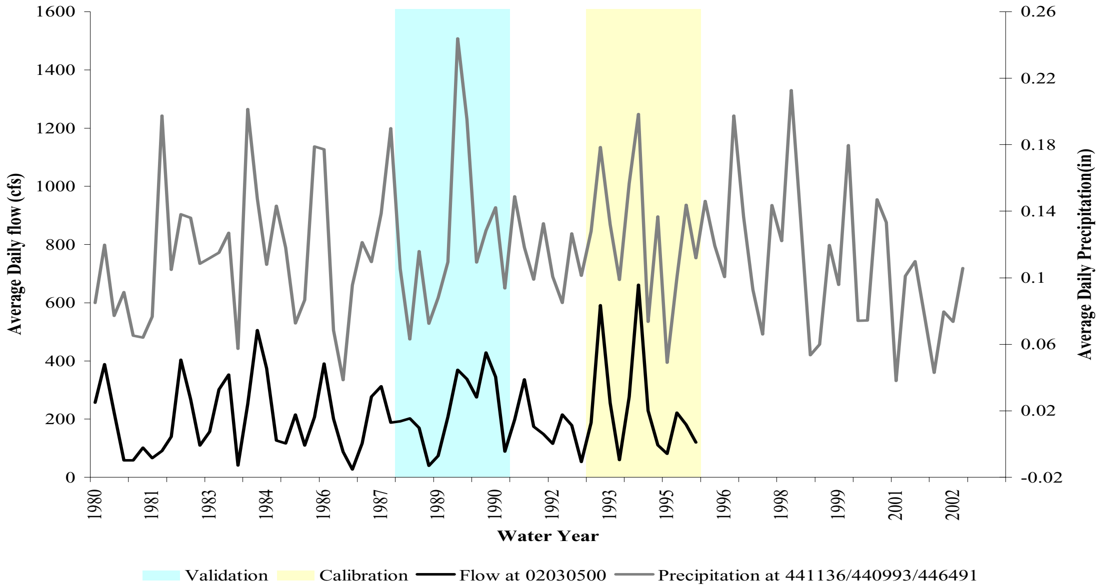

Figure 4.4 Seasonal Historical Flow (USGS Station 02030500) and Precipitation (Stations 441136, 440993, 446491) Data

Table 4.4 Comparison of modeled period to historical records.

	Mean Flow (cfs)				**Precipitation (in/day)**			
	USGS Station 02030500				**Primary Station 441136 Secondary Stations 440993/446491***			
	Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**
	Historical Record (1926 - 1995)				**Historical Record (1950 - 2003)**			
Mean	188.432	339.393	247.220	122.75	0.106	0.111	0.115	0.125
Variance	14,334	19,906	22,139	10,546	0.002	0.001	0.002	0.002
	Calibration & Validation Period (10/92-9/95, 10/87-9/90)							
Mean	182.196	491.667	221.766	96.674	0.111	0.159	0.117	0.116
Variance	0.458	0.137	0.207	0.145	0.436	0.060	0.477	0.227
	p-values				**p-values**			
Mean	0.458	0.137	0.207	0.145	0.436	0.060	0.477	0.227
Variance	9,625	55,621	1,425	1,088	0.003	0.003	0.001	0.000

*Secondary Station utilized only when Primary Station was off-line.

4.5 Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.,* animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Direct depositions by nocturnal animals were modeled as being deposited from 6:00 PM to 6:00 AM, and direct depositions by diurnal animals were modeled as being deposited from 6:00 AM to 6:00 PM. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.,* population). Depending on the timeframe of the simulation being run, different numbers should be used. Data representing 1998 were used for the water quality calibration period (1997-1999) and data representing 2001 were used for validation period (1999-2002). Data representing 2006 were used for the allocation runs in order to represent current conditions.

4.5.1 Point Sources

There are 10 permitted point discharges in the James River Tributaries in Albemarle and Buckingham Counties. Seven of these facilities are permitted for fecal control, with design discharges ranging from 0.0004 - 0.3 MGD (see Table 3.4). The design flow capacity was used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu/100 ml to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels. For calibration and current condition runs, a lower value of fecal coliform concentration was used, based upon a regression analysis relating Total Residual Chlorine (TRC) levels and fecal coliform concentrations. Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

4.5.2 Private Residential Sewage Treatment

The number of septic systems in the 41 subwatersheds modeled for water quality in the James River Tributaries in Albemarle and Buckingham Counties was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the watersheds to enumerate the septic systems. Each residential land use area was assigned a number of septic systems based on census data. A total of 3,127 septic systems were estimated in the James River Tributaries in Albemarle and Buckingham Counties Study Area in 1998. During allocation runs, the number of households was projected to 2006, based on current growth rates (USCB, 2000) resulting in 3,596 septic systems (Table 3.6).

4.5.2.1 Failing Septic Systems

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of the TMDLs for the James River Tributaries in Albemarle and Buckingham Counties Study Area. Total septic systems in each category were calculated using U.S. Census Bureau block demographics. The applicable failure rate was multiplied by each total and summed to get the total failing septic systems per subwatershed. The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors to account for more frequent failures during wet months.

4.5.2.2 Uncontrolled Discharges

Uncontrolled discharges were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category “other means” were assumed to be disposing sewage via uncontrolled discharges. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. Fecal coliform loads for each discharge were calculated based on the fecal density of human waste and the waste load for the average size household in the subwatershed. The loadings from uncontrolled discharges were applied directly to the stream in the same manner that point sources are handled in the model (Table 3.6).

4.5.2.3 Sewer System Overflows

No sewer system overflows were modeled in the James River Tributaries in Albemarle and Buckingham Counties due to the lack of representable sewer networks within the region of interest.

4.5.3 Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The amount of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock numbers determined for 2006 were used for the allocation runs, while these numbers were projected back to 1998 for the calibration and 2002 for validation runs. The numbers are based on data provided by VCE, DCR, NRCS, PFSWCD, TJSWCD, as well as taking into account growth rates in Albemarle and Buckingham counties as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1995; VASS, 2002). For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.12). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

4.5.3.1 Land Application of Collected Manure

Collection of livestock manure occurs on various beef, horse, and swine farms. For each livestock animal type in the drainage area, the average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Table 3.10. No dairy farms were reported with the James River Tributaries in Albemarle and Buckingham Counties and therefore, no dairy waste collection and application were modelded. If beef cattle were reported as being confined for some percentage of time, the waste produced while in confinement was estimated. Finally, values for the percentage of loafing lot waste collected, based on data provided by SWCD representatives and local stakeholders, were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.11). Swine in confinement were assumed to be confined 100% of the time with all waste stored in a lagoon. Stored waste was spread on pastured land. It was assumed that 100% of land-applied waste is available for transport in surface runoff unless the waste is incorporated in the soil by plowing during seedbed preparation. Percentage of cropland plowed and amount of waste incorporated was adjusted using calibration for the months of planting.

4.5.3.2 Deposition on Land

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the study entitled "Modeling Cattle Stream Access" conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR. The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horse and goat) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land use type was area-weighted.

4.5.3.3 Direct Deposition to Streams

Beef cattle are the primary sources of direct deposition by livestock in the James River Tributaries in Albemarle and Buckingham Counties. The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in "stream access" areas was calculated based on the "Modeling Cattle Stream Access" study. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 30% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

4.5.4 Biosolids

Investigation of VDH data indicated that biosolids applications have occurred within the James River Tributaries in Albemarle and Buckingham Counties. With urban populations served by waste water treatment plants growing, the disposal of biosolids will take on increasing importance. Class B biosolids are permitted to contain up to 1,995,262 cfu/g-dry, as compared with approximately 240 cfu/g-dry for dairy waste. Records of biosolids applications were obtained from the Farms Services Agency, the VDH and from biosolids applicators, enabling the water quality modeling to be carried out in an "as applied" fashion, wherein the water quality model received land based inputs of biosolids loads on the day in which they actually occurred. During both model calibration and allocation runs, biosolids were modeled as having a fecal concentration of 157,835 cfu/g, the mean value of measured biosolids concentrations observed in several years of samples supplied by VDH for sources applied during 2001 to 2005. Applications were modeled as being spread onto the land surface over a six hour period on the date of the reported application. In the case of a multiple day application, loads were split evenly over the period reported. An assumption of proper application was made, wherein no biosolids were modeled as being spread in stream corridors. During this analysis, the water quality model predicted that in the majority of watersheds in this study, biosolids application resulted in a negligible increase in instantaneous violations. However, the total loading sensitivity analysis (see section 4.6.2, Figures 4.6 through 4.7) predicted a linear relationship between increased fecal coliform concentrations in land applications and concentrations in the stream, implying that a significant increase in the area of land eligible for biosolids application could potentially have a negative impact on water quality.

4.5.5 Wildlife

For each species of wildlife modeled, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Table 3.16). An example of one of these layers is shown in Figure 4.2. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the waste load, fecal coliform densities, and number of animals for each species.

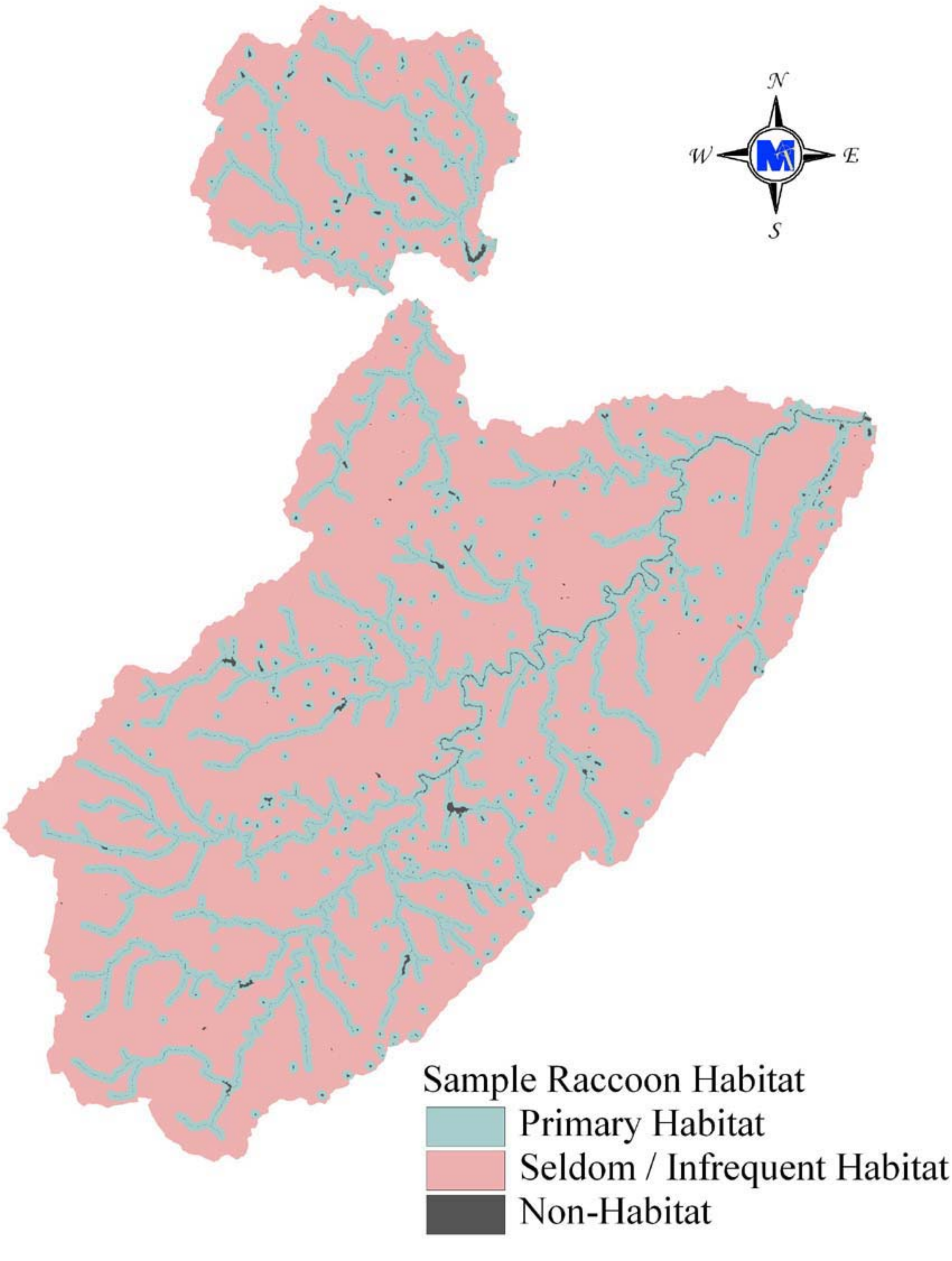

Figure 4.5 Example of raccoon habitat layer in the watershed of the James River tributaries in Albemarle and Buckingham counties, as developed by MapTech.

No seasonal variation was assumed for any species. For each species, a portion of the total waste load was considered land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.17). It was estimated that, for all animals other than beaver, 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams. No long-term (1997–2006) adjustments were made to wildlife populations, as there was no available data to support such adjustments.

4.5.6 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), waste load, and fecal coliform density are reported in Section 3.3.3. Waste from pets was distributed on residential land uses. The locations of households were taken from the 1990 and 2000 Census (USCB, 1990 and USCB, 2000). The number of animals per subwatershed was determined by multiplying the number of households in each watershed by the population density of each animal. The amount of fecal coliform deposited daily by pets in each land use segment was calculated by multiplying the waste load, fecal coliform density, and number of animals for both cats and dogs. The waste load was assumed not to vary seasonally. The populations of cats and dogs were projected from 1990 data to 1998, 2002 and 2006.

4.6 Sensitivity Analysis

Sensitivity analyses are performed to determine a model's response to changes in certain parameters. This process involves changing a single parameter a certain percentage from a baseline value while holding all other parameters constant. This process is repeated for several parameters in order to gain a complete picture of the model's behavior. The information gained during sensitivity analysis can aid in model calibration, and it can also help to determine the potential effects of uncertainty in parameter estimation. Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.,* seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads). Additional analyses were performed to define the sensitivity of the modeled system to growth or technology changes that impact waste production rates.

4.6.1 Hydrology Sensitivity Analysis

The HSPF parameters adjusted for the hydrologic sensitivity analysis are presented in Table 4.5, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value, and the model was run for water years 1993-1995. Where an increase of 50% exceeded the maximum value for the parameters, the maximum value was used and the parameters increased over the base value were reported. The hydrologic quantities of greatest interest in a fecal coliform model are those that govern peak flows and low flows. Peak flows, being a function of runoff, are important because they are directly related to the transport of fecal coliforms from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration such as INFILT (Infiltration), LZSN (Lower Zone Storage), and by UZSN (Upper Zone Storage), which governs surface transport, and LZETP (Lower Zone Evapotranspiration), which affects soil moisture. Low flows are important in a water quality model because they control the level of dilution during dry periods. Parameters with the greatest influence on low flows (as evidenced by their influence in the *Low Flows* and *Summer Flow Volume* statistics) were AGWRC (Groundwater Recession Rate), BASETP (Base Flow Evapotranspiration), LZETP, interception, groundwater flow to deep recharge, and, infiltration. The responses of these and other hydrologic outputs are reported in Table 4.6.

Table 4.5 HSPF base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
LZSN	Lower Zone Nominal Storage	in	4.91-6.00
INFILT	Soil Infiltration Capacity	in/hr	0.0348-0.0973
AGWRC	Groundwater Recession Rate	---	0.999-0.999
BASETP	Base Flow Evapotranspiration	---	0.1-0.1
INTFW	Interflow Inflow	---	2.0-2.0
DEEPFR	Groundwater Inflow to Deep Recharge	---	0.1-0.1
MON-INTERCEP	Monthly Interception Storage Capacity	in	0.01-0.3
MON-UZSN	Monthly Upper Zone Nominal Storage	in	0.2-0.99
MON-LZETP	Monthly Lower Zone Evapotranspiration	in	0.1-0.45

Table 4.6 HSPF Sensitivity analysis results for hydrologic model parameters, Slate River.

		Percent Change In											
Model Parameter	Parameter Change (%)	Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume	Winter Storm Volume	Spring Storm Volume	Summer Storm Volume	Fall Storm Volume
AGWRC[1]	0.85	26.84	27.42	-55.09	28.66	13.55	9.50	39.29	26.96	28.72	13.68	9.82	39.44
AGWRC[1]	0.92	25.81	21.31	-43.98	28.50	13.00	-0.38	38.54	25.92	28.56	13.12	-0.11	38.69
AGWRC[1]	0.96	24.72	16.41	-28.04	28.69	12.68	-6.77	35.58	24.84	28.75	12.80	-6.54	35.72
AGWRC[1]	0.999	22.15	11.30	3.47	25.73	22.92	-4.63	21.55	22.24	25.78	23.03	-4.46	21.65
BASETP	-50	5.04	-1.73	59.91	-0.25	11.76	38.31	1.10	-1.48	-3.45	3.37	14.09	-5.88
BASETP	-10	0.82	-0.29	9.36	-0.01	2.04	5.23	0.31	0.66	-0.09	1.83	4.70	0.13
BASETP	10	-0.75	0.27	-8.44	0.00	-1.84	-4.57	-0.34	-0.69	0.03	-1.76	-4.38	-0.28
BASETP	50	-3.11	1.23	-34.24	-0.08	-7.82	-16.19	-1.87	-3.03	-0.05	-7.73	-16.00	-1.79
DEEPFR	-50	3.07	0.97	11.45	2.29	4.57	6.45	2.51	2.99	2.25	4.47	6.21	2.42
DEEPFR	-10	0.61	0.19	2.26	0.45	0.90	1.27	0.50	0.59	0.45	0.89	1.23	0.48
DEEPFR	10	-0.60	-0.19	-2.24	-0.45	-0.90	-1.26	-0.50	-0.59	-0.45	-0.88	-1.22	-0.48
DEEPFR	50	-2.99	-0.95	-11.06	-2.24	-4.42	-6.21	-2.48	-2.95	-2.22	-4.36	-6.05	-2.43
INFILT	-50	5.25	18.34	-41.62	7.91	-3.74	1.08	8.29	5.33	7.95	-3.65	1.35	8.38
INFILT	-10	0.71	2.86	-7.51	1.27	-0.81	-0.73	1.20	0.76	1.30	-0.75	-0.57	1.26
INFILT	10	-0.61	-2.55	7.14	-1.17	0.81	0.93	-1.04	-0.67	-1.20	0.74	0.72	-1.11
INFILT	50	-2.37	-10.63	33.08	-5.17	3.90	6.04	-4.01	-2.81	-5.39	3.34	4.51	-4.50
INTFW	-50	-1.63	2.73	-0.40	-1.10	-3.25	-1.65	-1.42	-1.64	-1.10	-3.26	-1.67	-1.43
INTFW	-10	-0.74	0.07	-1.92	-0.52	-1.27	-1.33	-0.61	-0.73	-0.51	-1.25	-1.29	-0.60
INTFW	10	-0.49	-0.34	-2.54	-0.40	-0.57	-1.20	-0.41	-0.47	-0.40	-0.55	-1.15	-0.39
INTFW	50	-0.17	-0.42	-3.41	-0.28	0.39	-1.00	-0.16	-0.15	-0.27	0.42	-0.93	-0.14

[1]Actual parameter value used

Table 4.6 HSPF Sensitivity analysis results for hydrologic model parameters, Slate River (continued).

Model Parameter	Parameter Change (%)	Percent Change In: Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume	Winter Storm Volume	Spring Storm Volume	Summer Storm Volume	Fall Storm Volume
LZSN	-50	9.51	12.33	-10.06	13.43	4.70	-15.45	12.38	9.59	13.47	4.79	-15.32	12.47
LZSN	-10	1.39	1.74	-1.40	2.14	1.04	-3.20	1.39	1.40	2.15	1.05	-3.17	1.41
LZSN	10	-1.27	-1.58	1.06	-1.96	-1.04	2.88	-1.16	-1.28	-1.97	-1.05	2.86	-1.17
LZSN	50	-5.62	-6.65	2.37	-8.48	-5.20	11.17	-4.65	-5.65	-8.49	-5.23	11.15	-4.68
CEPSC	-50	2.99	0.82	15.21	1.25	4.82	11.84	2.65	2.87	1.19	4.67	11.48	2.52
CEPSC	-10	-0.04	-0.08	0.62	-0.21	0.10	0.86	-0.06	-0.05	-0.21	0.09	0.85	-0.07
CEPSC	10	-1.15	-0.32	-4.71	-0.68	-1.81	-3.46	-0.93	-1.12	-0.67	-1.77	-3.37	-0.90
CEPSC	50	-2.87	-0.70	-12.28	-1.47	-5.27	-8.21	-2.35	-2.82	-1.44	-5.20	-8.06	-2.29
LZETP	-50	15.20	13.20	23.95	9.47	7.72	45.95	25.06	15.24	9.49	7.76	46.25	25.12
LZETP	-10	2.54	2.30	4.91	1.33	0.97	8.90	4.64	2.55	1.34	0.98	8.97	4.66
LZETP	10	-3.70	-2.61	-9.25	-2.20	-2.79	-11.28	-5.53	-3.68	-2.19	-2.76	-11.25	-5.51
LZETP	50	-11.43	-8.24	-26.23	-6.96	-8.13	-32.22	-17.91	-11.40	-6.94	-8.10	-32.24	-17.89
UZSN	-50	8.22	14.40	-13.38	5.64	5.51	25.98	10.97	8.28	5.66	5.58	26.29	11.04
UZSN	-10	0.81	2.39	-4.00	0.55	-0.24	2.60	1.74	0.83	0.57	-0.21	2.70	1.77
UZSN	10	-1.77	-2.34	-0.84	-1.33	-1.37	-4.35	-2.32	-1.76	-1.33	-1.36	-4.34	-2.31
UZSN	50	-5.84	-9.58	3.69	-4.73	-2.73	-12.56	-8.93	-5.86	-4.74	-2.75	-12.66	-8.96

[1]Actual parameter value used

4.6.2 Water Quality Parameter Sensitivity Analysis

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 1997 through 1999. The four HSPF parameters impacting the model's water quality response (Table 4.7) were increased and decreased by amounts that were consistent with the range of values for the parameter. All three parameters had noticeable influence on monthly geometric mean concentration (Table 4.8). Graphical depictions of the results of this sensitivity analysis can be seen in Figures 4.6 through 4.8.

Table 4.7 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	0-4.5E+12
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	0-2.8
FSTDEC	In-stream First Order Decay Rate	1/day	0.88-1.75

Table 4.8 Percent change in average monthly *E. coli* geometric mean for the years 1997-1999 for outlet of Slate River.

Model	Parameter Change	Percent Change in Average Monthly *E. coli* Geometric Mean for 1997-1999											
Parameter	(%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	33.01	36.96	38.30	37.87	40.58	38.11	33.03	25.38	29.82	34.78	30.79	35.59
FSTDEC	-10	5.11	5.63	5.87	5.75	6.24	5.71	4.89	3.81	4.58	5.34	4.84	5.37
FSTDEC	10	-4.59	-5.03	-5.26	-5.14	-5.58	-5.08	-4.34	-3.40	-4.11	-4.79	-4.37	-4.79
FSTDEC	50	-19.20	-20.81	-21.73	-21.20	-23.03	-20.80	-17.70	-14.11	-17.10	-19.90	-18.41	-19.80
SQOLIM	-50	-13.13	-10.98	-14.28	-12.40	-19.24	-13.09	-9.34	-5.36	-7.66	-7.53	-8.45	-13.14
SQOLIM	-25	-6.53	-5.24	-6.34	-5.24	-8.37	-5.87	-4.36	-2.38	-3.37	-3.32	-3.77	-6.39
SQOLIM	25	6.33	4.99	5.50	4.16	6.46	4.44	3.44	1.83	2.60	2.58	3.00	5.74
SQOLIM	50	12.62	9.99	10.78	7.81	11.97	8.16	6.51	3.44	4.93	4.84	5.56	11.09
WSQOP	-50	13.42	15.84	27.87	20.40	26.01	14.34	10.96	5.05	7.81	7.66	5.92	9.70
WSQOP	-10	1.61	1.95	3.23	2.41	3.10	1.79	1.22	0.60	0.91	0.99	0.74	1.22
WSQOP	10	-1.72	-2.09	-3.40	-2.55	-3.31	-1.92	-1.30	-0.65	-0.97	-1.08	-0.80	-1.33
WSQOP	50	-6.32	-7.72	-12.17	-9.29	-12.03	-7.09	-4.62	-2.32	-3.50	-4.01	-2.97	-4.91

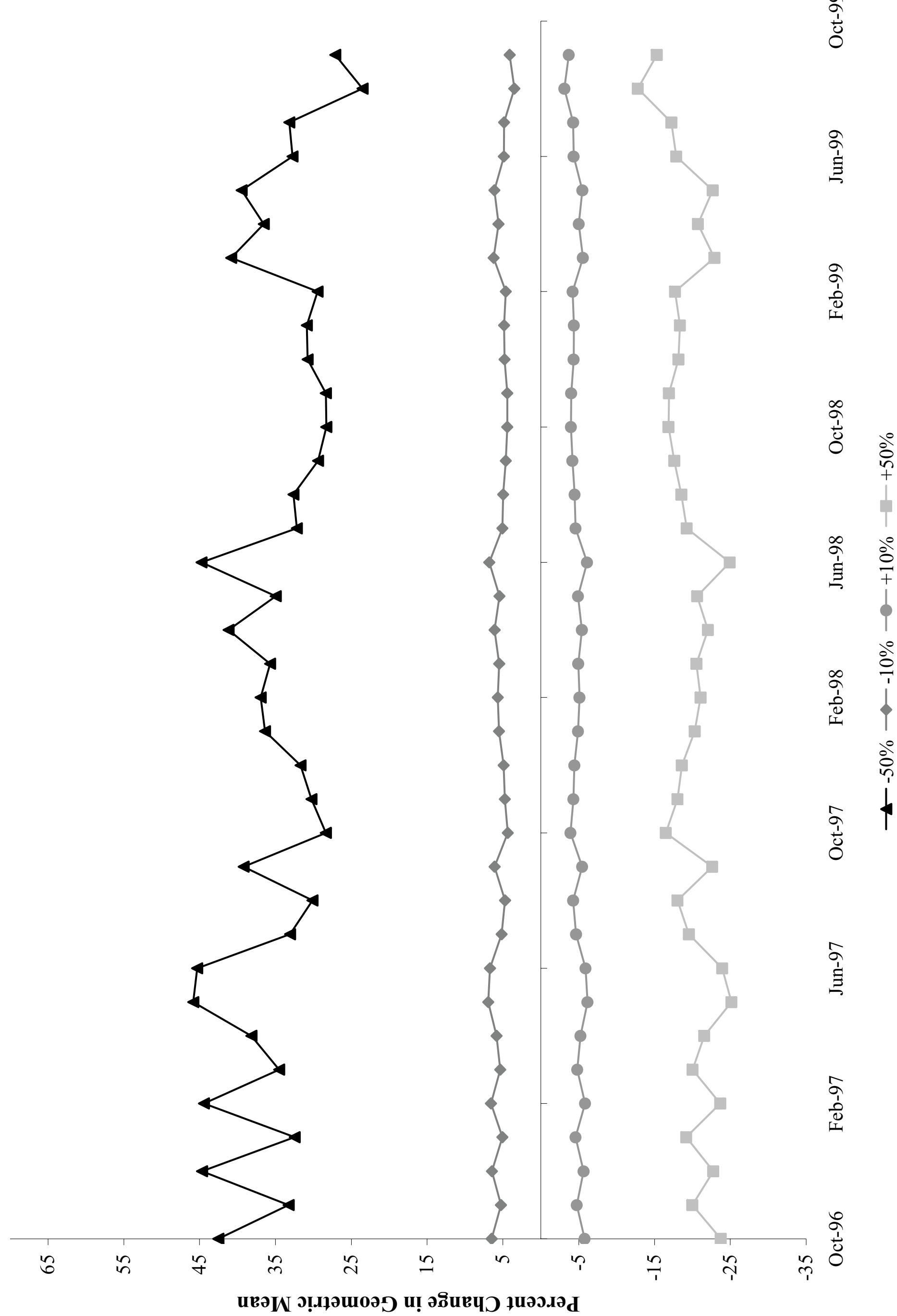

Figure 4.6 Results of sensitivity analysis on monthly geometric-mean concentrations at outlet of Slate River, as affected by changes in the in-stream first-order decay rate (FSTDEC).

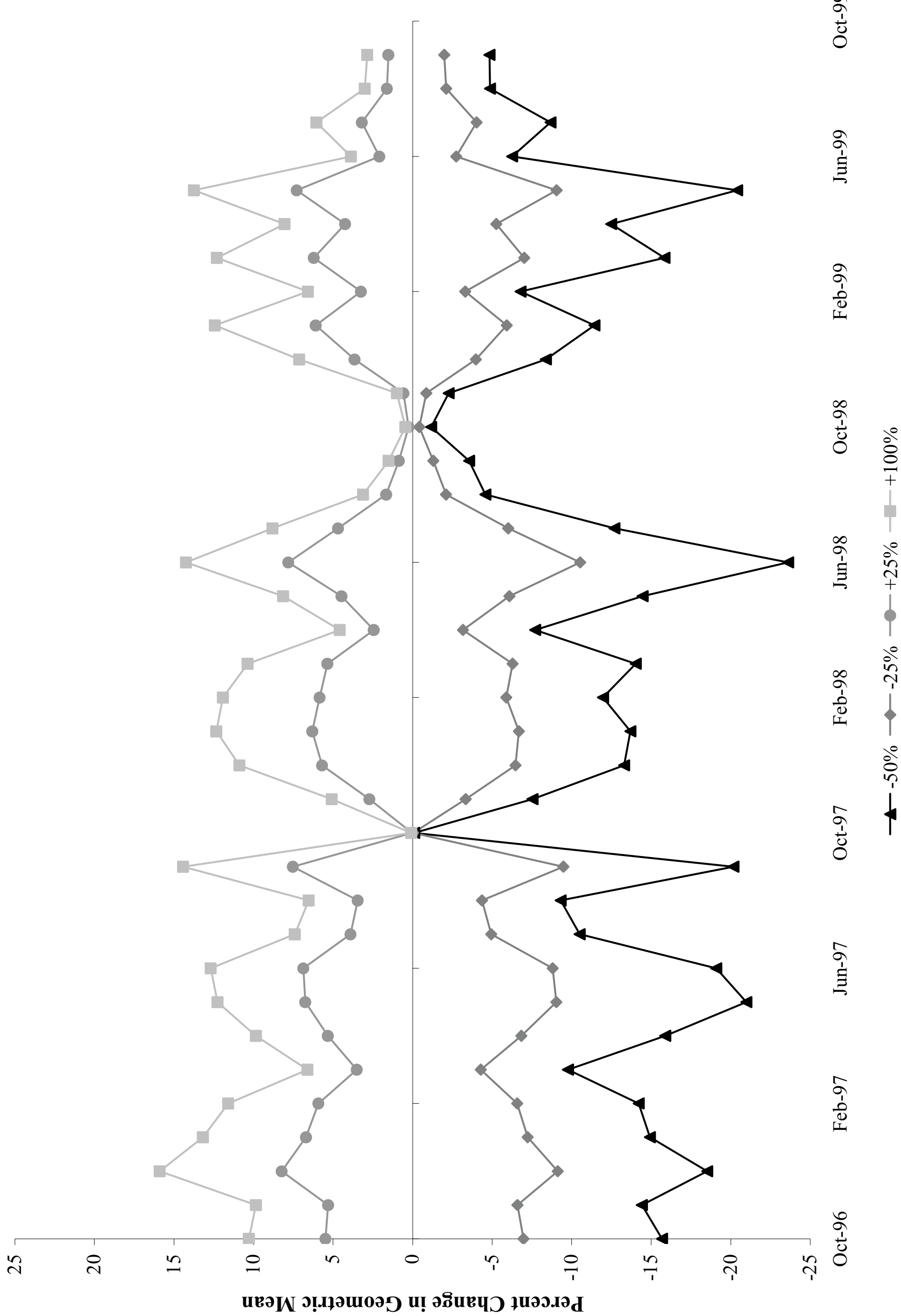

Figure 4.7 Results of sensitivity analysis on monthly geometric-mean concentrations at outlet of Slate River, as affected by changes in maximum fecal accumulation on land (MON-SQOLIM).

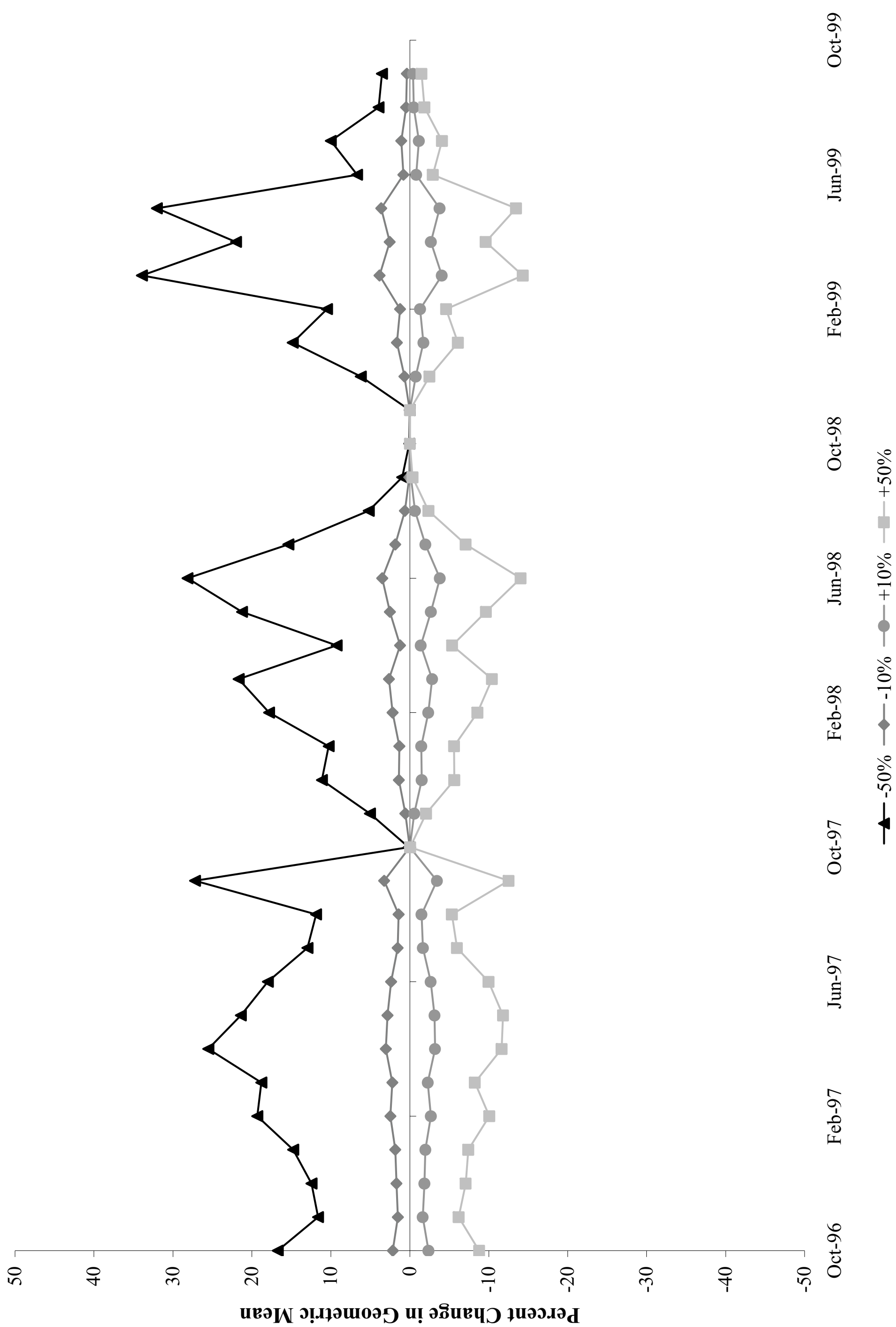

Figure 4.8 Results of sensitivity analysis on monthly geometric-mean concentrations at outlet of Slate River, as affected by changes in the wash-off rate from land surfaces (WSQOP).

In addition to analyzing the sensitivity of the model response to changes in water quality transport and die-off parameters, the response of the model to changes in land-based and direct loads was also analyzed. It is evident in Figures 4.6 through 4.8 that the model predicts a linear relationship between increased fecal coliform concentrations in both land and direct applications, and total load reaching the stream. The magnitude of this relationship differs greatly between land applied and direct loadings; a 100% increase in the land applied loads results in an increase of over 90% in stream loads, while a 100% increase in direct loads results in less than a 10% increase in stream loads. In contrast, the sensitivity analysis of geometric mean concentrations showed that both land based loads and direct loads had great impact (Figures 4.9 through 4.11).

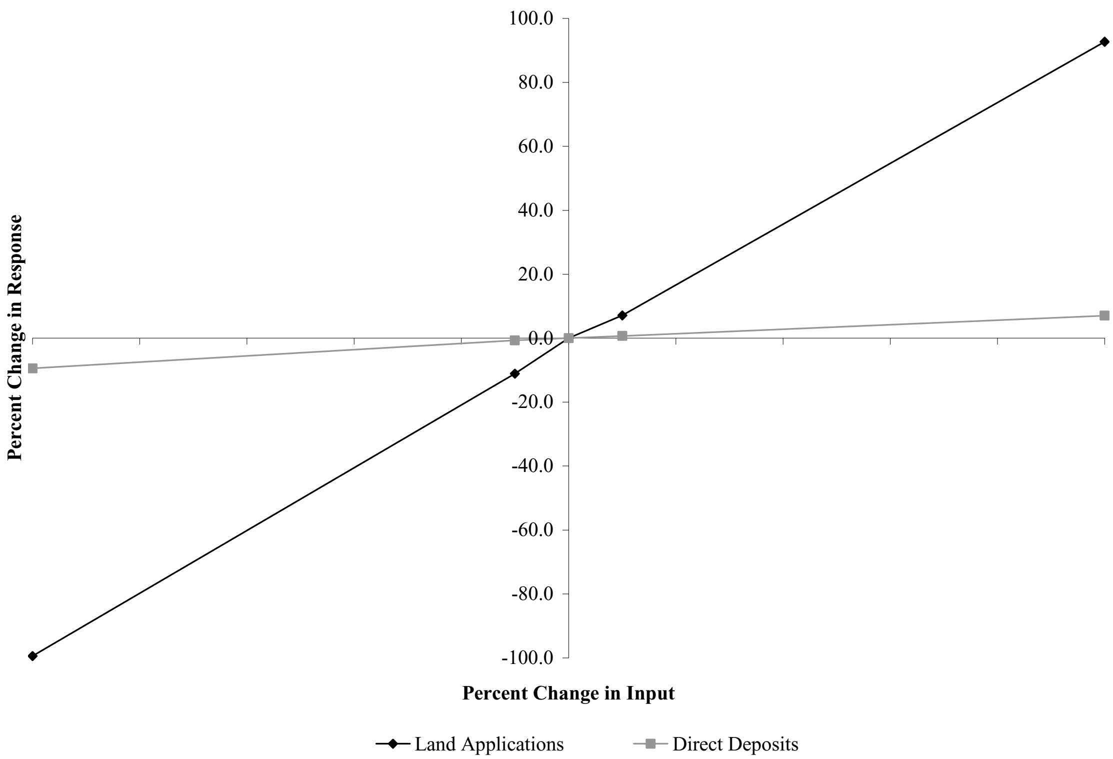

Figure 4.9 Results of total loading sensitivity analysis for outlet of Slate River.

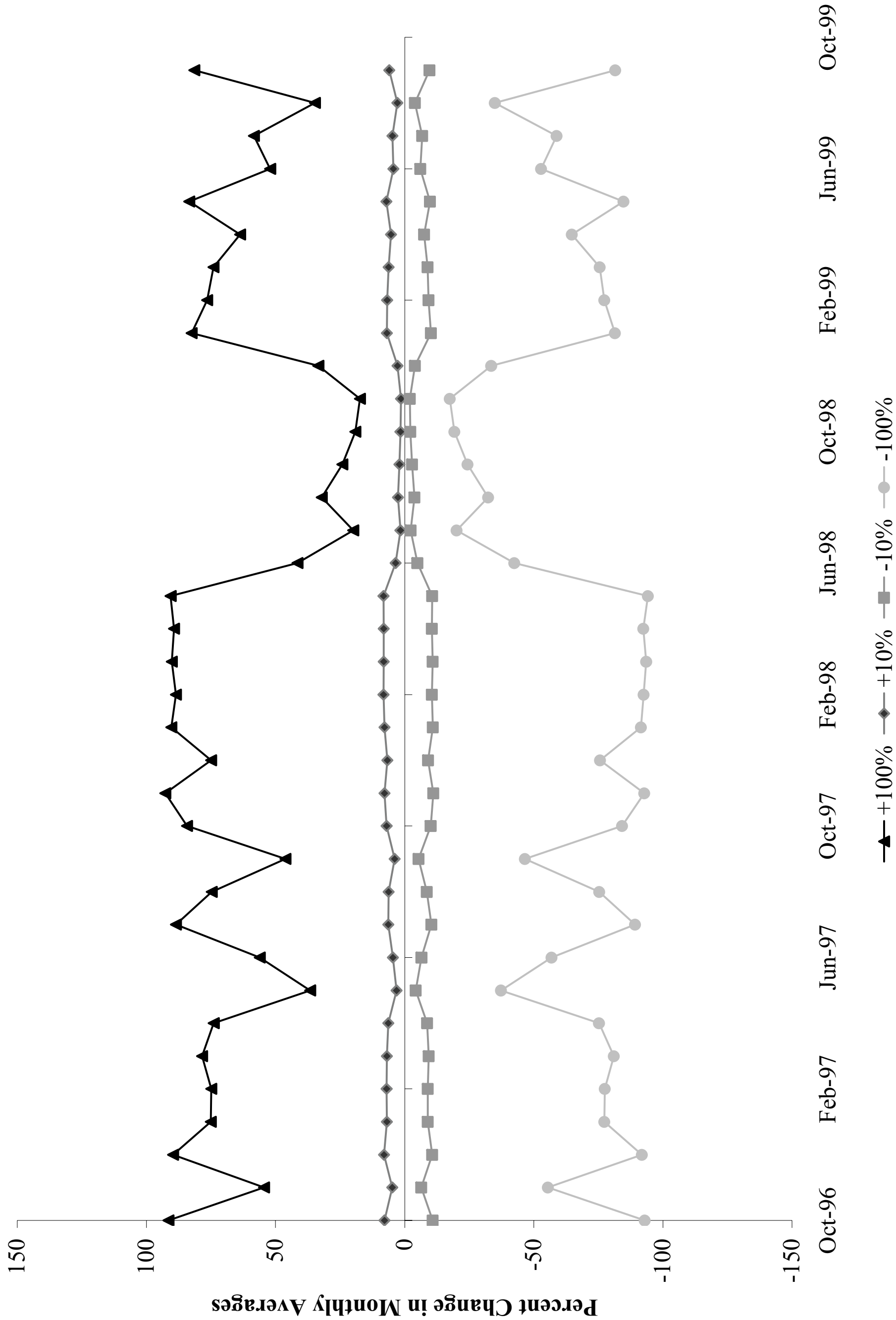

Figure 4.10 Results of sensitivity analysis on monthly geometric-mean concentrations for Slate River watershed, as affected by changes in land-based loadings.

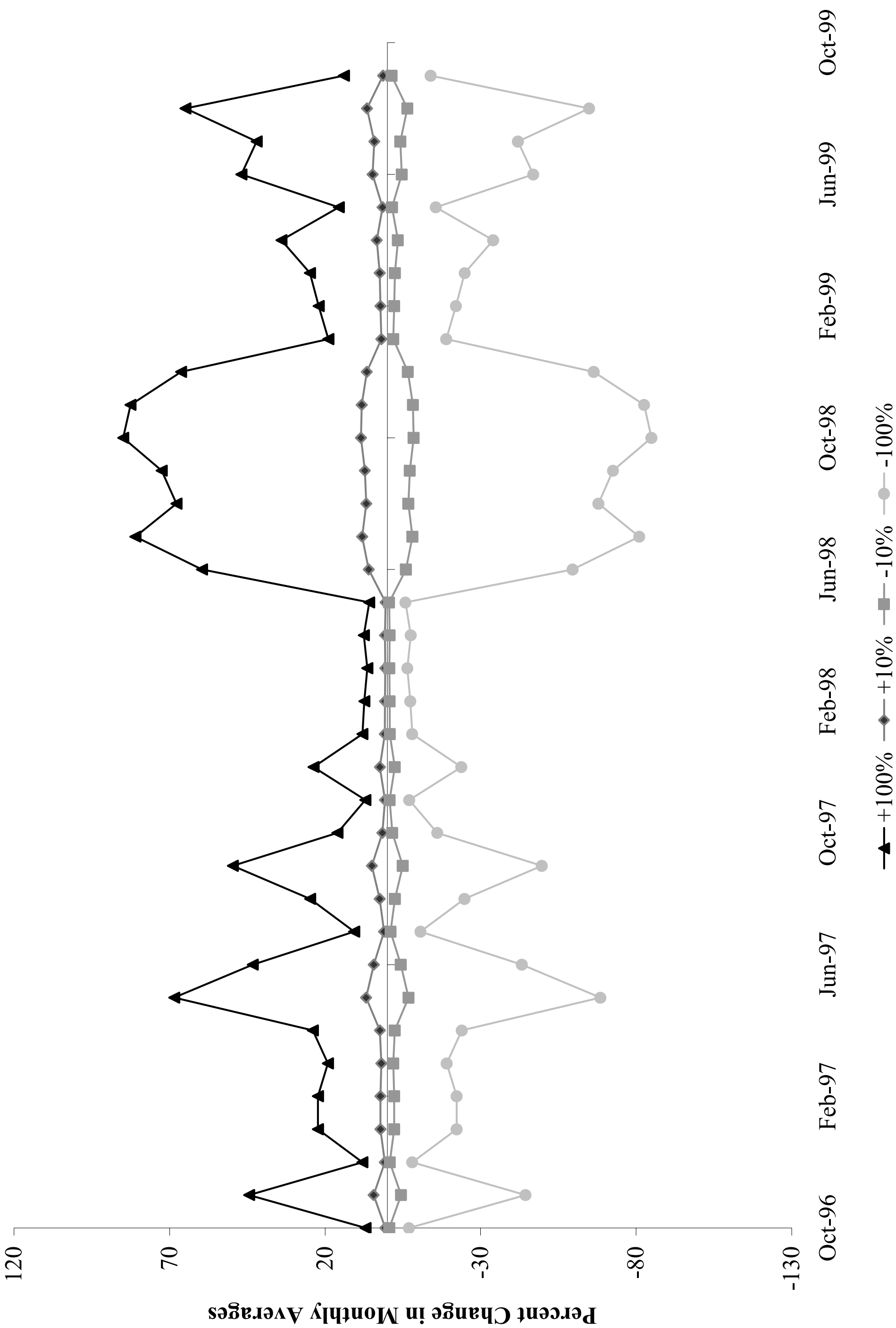

Figure 4.11 Results of sensitivity analysis on monthly geometric-mean concentrations for Slate River watershed, as affected by changes in loadings from direct nonpoint sources.

4.7 Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

4.7.1 Hydrologic Calibration and Validation

HSPF parameters that were adjusted during the hydrologic calibration represented: the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), the amount of soil water contributing to interflow (INTFW), deep groundwater inflow fraction (DEEPER), baseflow PET (BASETP), and groundwater recession flow (KVARY). Table 4.9 contains the possible range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions.

The model was calibrated for hydrologic accuracy using daily flow data from USGS Gaging Station 02030500 Slate River for the period October 1992 through September 1995 (Table 4.10). Figures 4.12 and 4.13 display comparisons of modeled versus observed data for the entire calibration period.

NCDC weather stations Buckingham (441136), Bremo (440993), and Palmyra (446491) were used to supply precipitation input for the HSPF model. For the entire modeling period, only daily precipitation values were available, thus daily rainfall values were interpolated to hourly values in order to provide model input on an hourly basis. This interpolation was performed in an HSPF utility called WDMUtil, and is referred to as disaggregation. In this process, a daily rainfall total is divided up into hourly values using a representative distribution scheme. Daily values were disaggregated using two different schemes: 1) a station matching disaggregation scheme and 2) a triangular disaggregation scheme. The station matching procedure involved identifying a rain gage reporting hourly data in close proximity to the study area whose daily total precipitation was within 5% of the total daily precipitation value of a station within the study area. In this case, the distribution of rainfall at the station within the watershed was disaggregated based on the precipitation pattern reported at the hourly station (Bremo #440993). When this condition failed, the precipitation was disaggregated based on a triangular distribution, over an 8-hour period.

Table 4.9 Model parameters utilized for hydrologic calibration.

Parameter	Units	Possible Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
LZSN	In	2.0 – 15.0	10.23-15.00	4.91-6.00
INFILT	in/hr	0.001 – 0.50	0.0696-0.1946	0.0626-0.1751
KVARY	l/in	0.0 – 5.0	0.0	0.2
AGWRC	l/day	0.85 – 0.999	0.98-0.98	0.993-0.993
DEEPFR	---	0.0 – 0.50	0.01-0.01	0.25-0.25
BASETP	---	0.0 – 0.20	0.01-0.01	0.1-0.1
AGWETP	---	0.0 – 0.20	0.01 – 0.01	0.01 – 0.01
CEPSC	in	0.01 - 0.40	0.01-0.2	0.01-0.4
UZSN	in	0.05 – 2.0	0.41-1.52	0.45-1.5
INTFW	---	1.0 – 10.0	2.0 – 2.0	1.0 – 1.0
IRC	l/day	0.30 – 0.85	0.5 – 0.5	0.3 – 0.3
LZETP	---	0.1 – 0.9	0.1-0.8	0.1-0.9

Table 4.10 Hydrology calibration criteria and model performance for period 10/1/1992 through 9/30/1995 at USGS Gaging Station 02030500 on Slate River (subshed 10).

Criterion	Observed	Modeled	Error
Total In-stream Flow:	165.07	150.42	-8.88
Upper 10% Flow Values:	80.81	71.75	-11.22
Lower 50% Flow Values:	24.67	22.38	-9.27
Winter Flow Volume	81.08	73.58	-9.26
Spring Flow Volume	36.98	38.60	4.40
Summer Flow Volume	16.30	12.52	-23.16
Fall Flow Volume	30.71	25.72	-16.27
Total Storm Volume	141.52	126.93	-10.31
Winter Storm Volume	75.25	67.76	-9.96
Spring Storm Volume	31.08	32.72	5.27
Summer Storm Volume	10.43	6.68	-35.95
Fall Storm Volume	24.75	19.77	-20.14

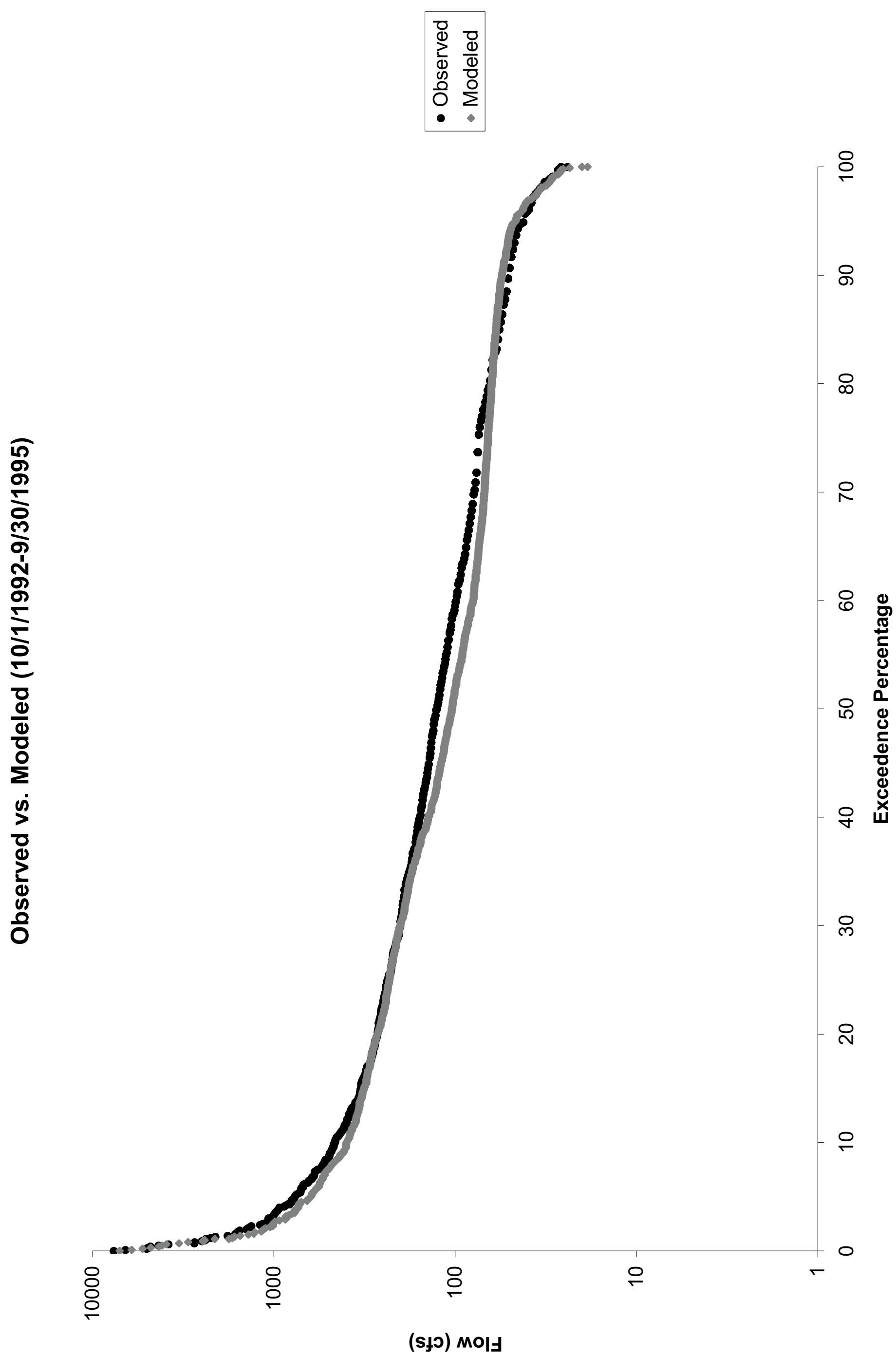

Figure 4.12 Slate River flow duration at USGS Gaging Station 02030500 for calibration period 10/1/1992 through 9/30/1995 (subshed 10).

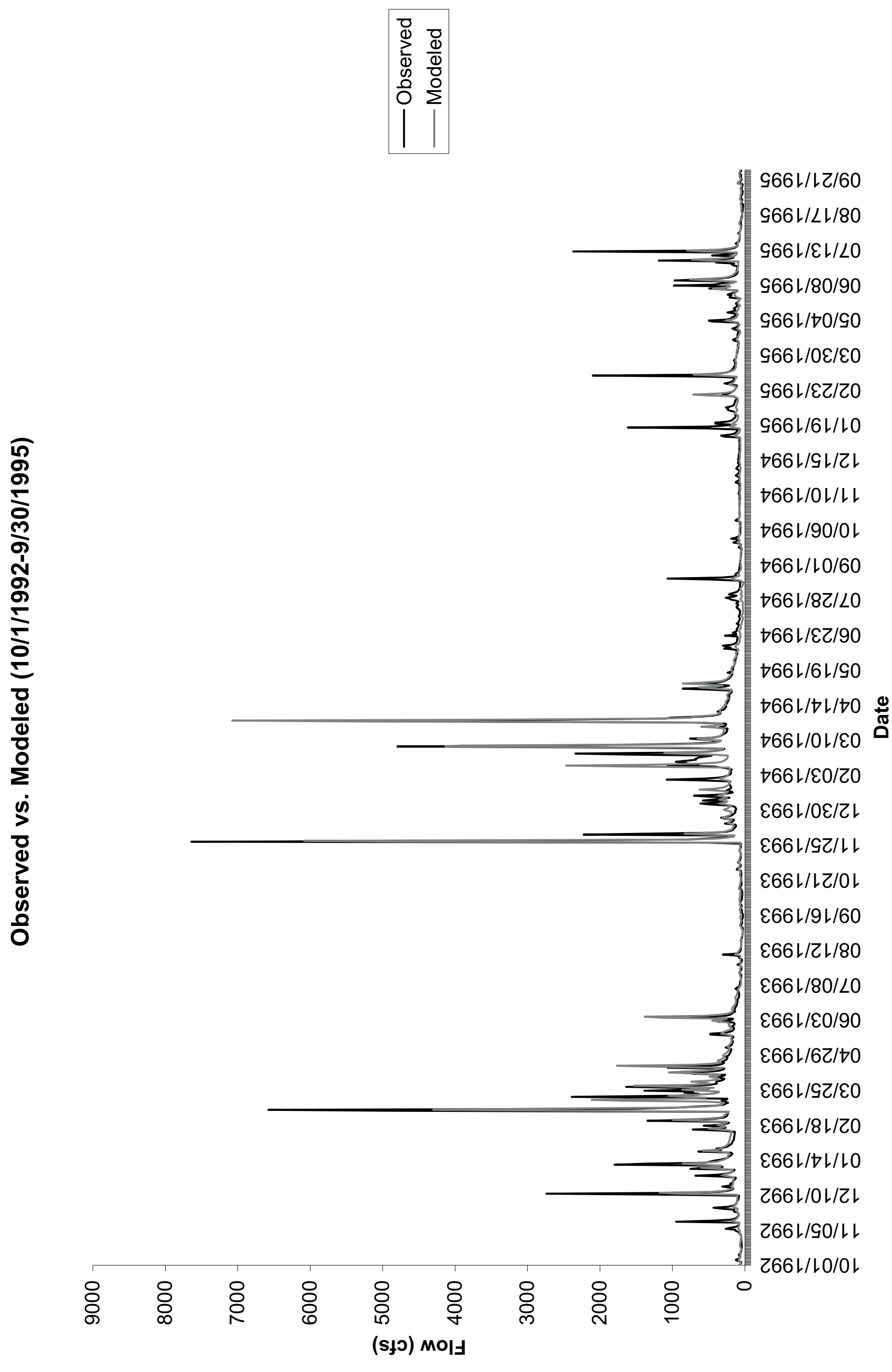

Figure 4.13 Calibration results for period 10/1/1992 through 9/30/1995 at USGS Gaging Station 02044500 on Slate River (subshed 10).

4.7.2 HSPF Hydrologic Validation

The hydrologic model was verified using stream flow data from 10/1/1987 to 9/30/1990. The resulting statistics are shown in Table 4.11. The percent error is within acceptable ranges for model validation. The hydrology validation results are shown in Figures 4.14 and 4.15.

Table 4.11 Hydrology validation criteria and model performance for Slate River for the period 10/01/1987 through 9/30/1990.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	151.98	165.52	8.91
Upper 10% Flow Values:	63.76	67.63	6.07
Lower 50% Flow Values:	27.06	30.86	14.04
Winter Flow Volume	46.20	44.49	-3.70
Spring Flow Volume	49.16	59.51	21.04
Summer Flow Volume	26.19	26.44	0.96
Fall Flow Volume	30.42	35.07	15.29
Total Storm Volume	136.64	147.06	7.63
Winter Storm Volume	42.40	39.89	-5.91
Spring Storm Volume	45.33	54.88	21.06
Summer Storm Volume	22.37	21.91	-2.07
Fall Storm Volume	26.54	30.39	14.48

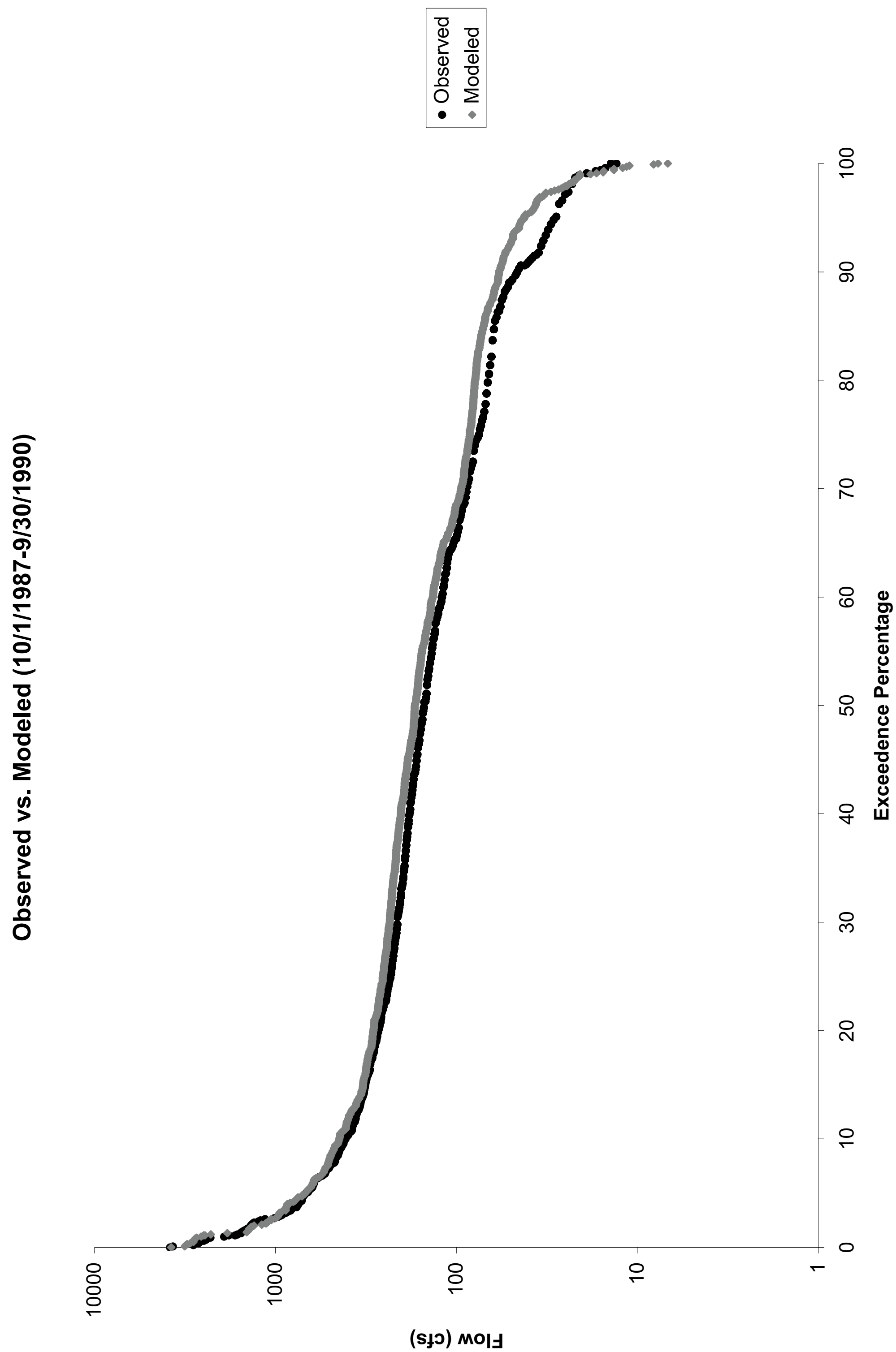

Figure 4.14 Slate River flow duration (10/01/1987 through 09/30/1990).

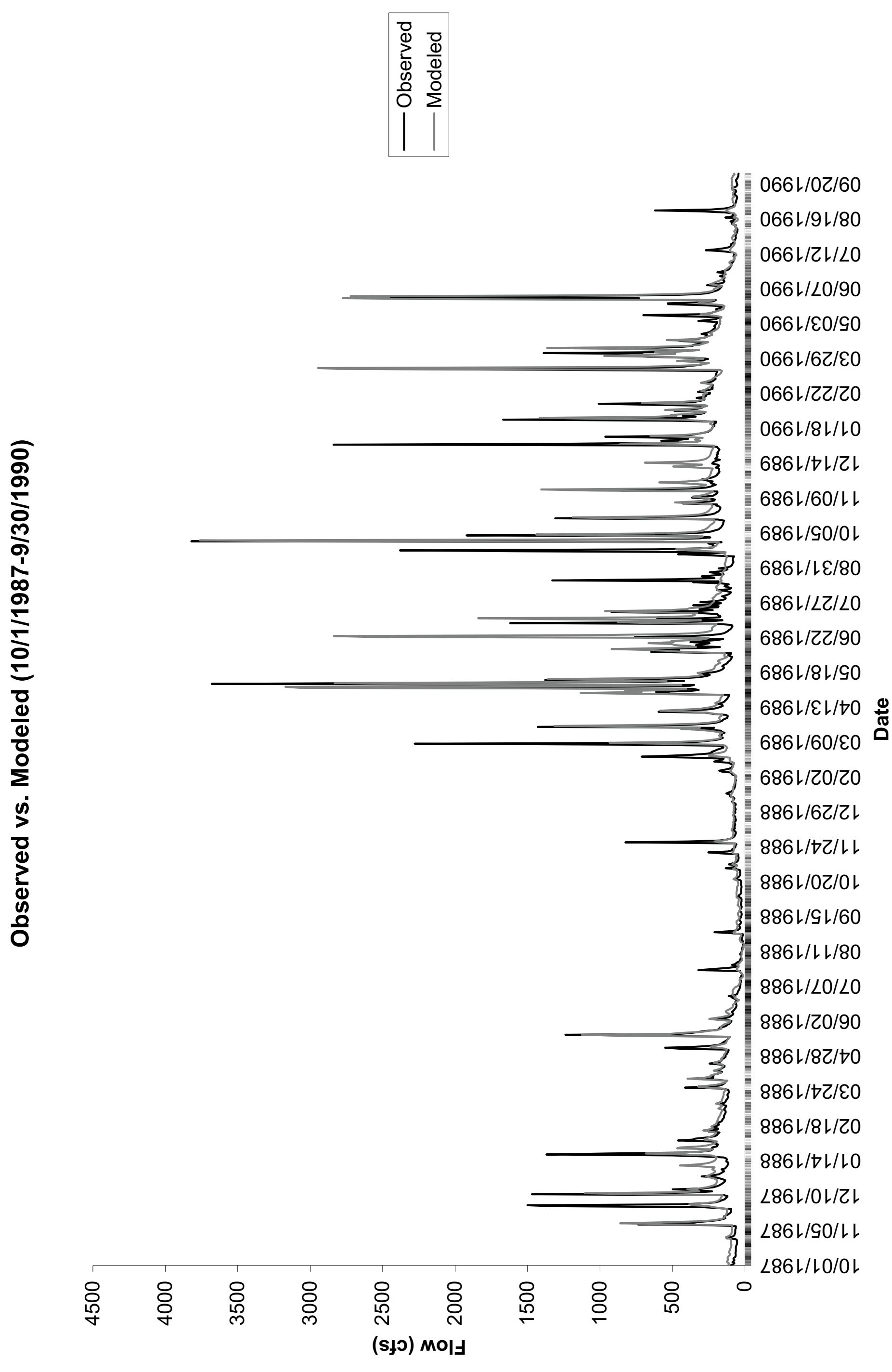

Figure 4.15 Hydrology validation results for Slate River (10/01/1987 through 09/30/1990).

4.7.3 Water Quality Calibration and Validation

Water quality calibration is complicated by a number of factors, some of which are described here. First, water quality concentrations (*e.g.,* fecal coliform concentrations) are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters such as fecal coliform concentration. Second, the concentration of fecal coliform is particularly variable. Variability in location and timing of fecal deposition, variability in the density of fecal coliform bacteria in feces (among species and for an individual animal), environmental impacts on regrowth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling fecal coliform concentrations. Additionally, the maximum values were at times censored at 8,000 cfu/100ml and, at other times, at 16,000 cfu/100ml. Limited amount of measured data for use in calibration and the practice of censoring both high (over 24,000 cfu/100 ml) and low (under 100 cfu/100 ml) concentrations impede the calibration process.

The water quality calibration was conducted from 10/1/1996 through 9/30/1999. Three parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), maximum accumulation on land (SQOLIM), and rate of surface runoff that will remove 90% of stored fecal coliform per hour (WSQOP). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled fecal coliform concentrations was established (Table 4.12). Figures 4.16 through 4.23 show the results of calibration.

Table 4.12 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	8E+6 to 1E+11	0 to 2.4E+13
WSQOP	in/hr	0.05 – 3.00	0.2 – 3.0	0.12 – 2.8
FSTDEC	1/day	0.01 – 10.00	1.15	0.05 to 1.0

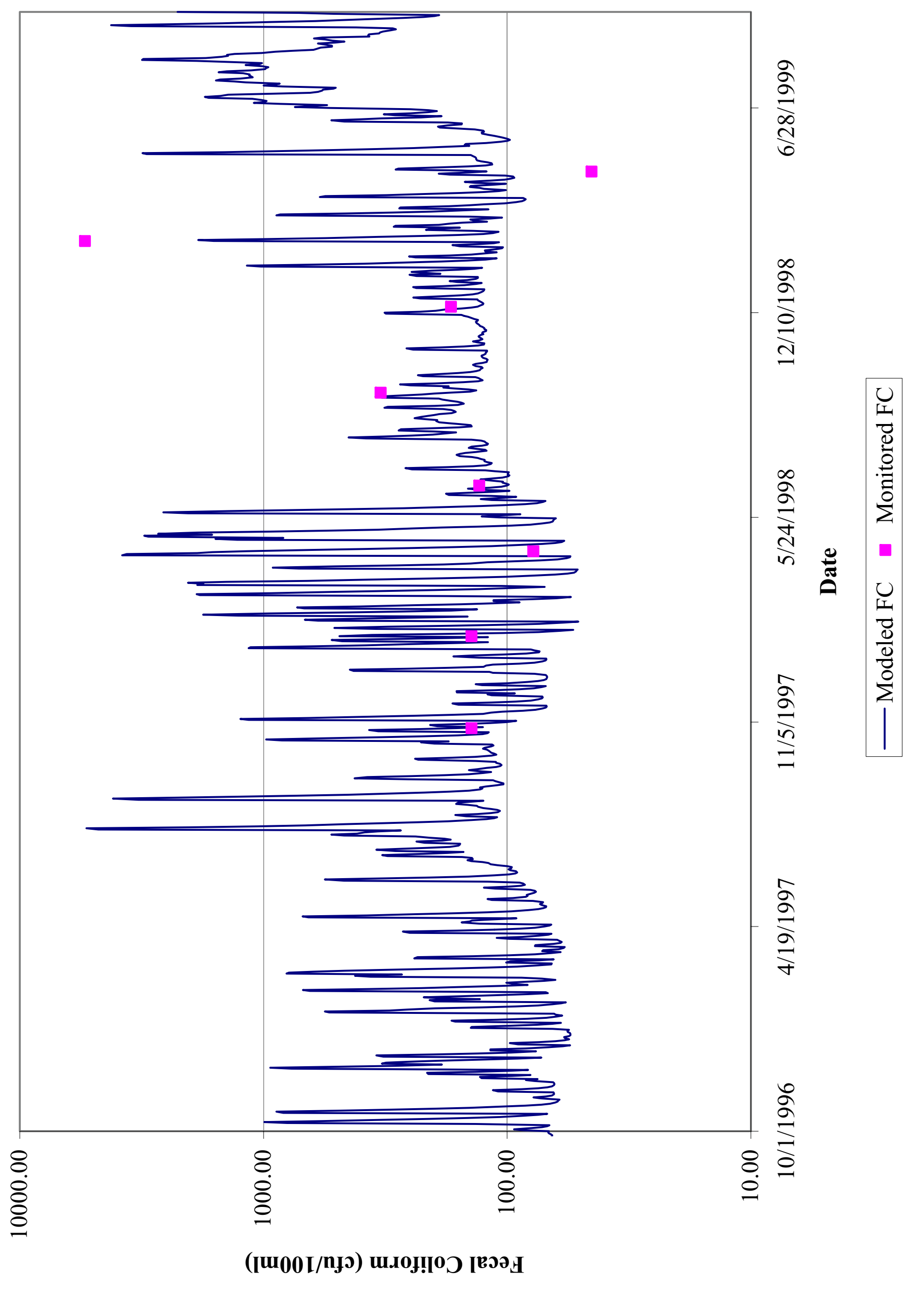

Figure 4.16 Quality calibration results for period 10/1/1996 to 9/30/1999 Frisby Branch, subshed 2 VADEQ Station 2-FRY000.35.

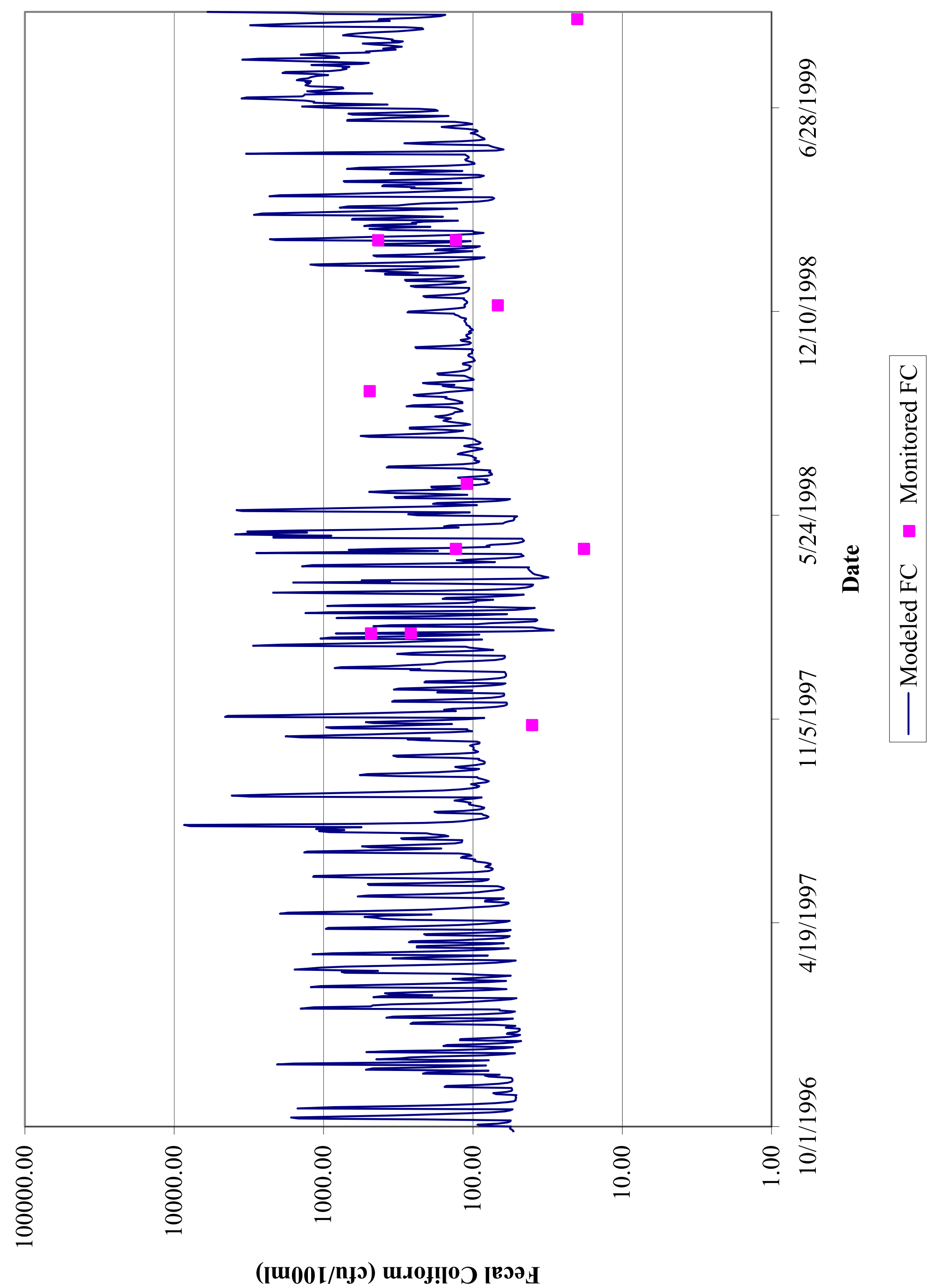

Figure 4.17 Quality calibration results for period 10/1/1996 to 9/30/1999 Austin Creek, subshed 13 VADEQ Station 2-AUS001.12.

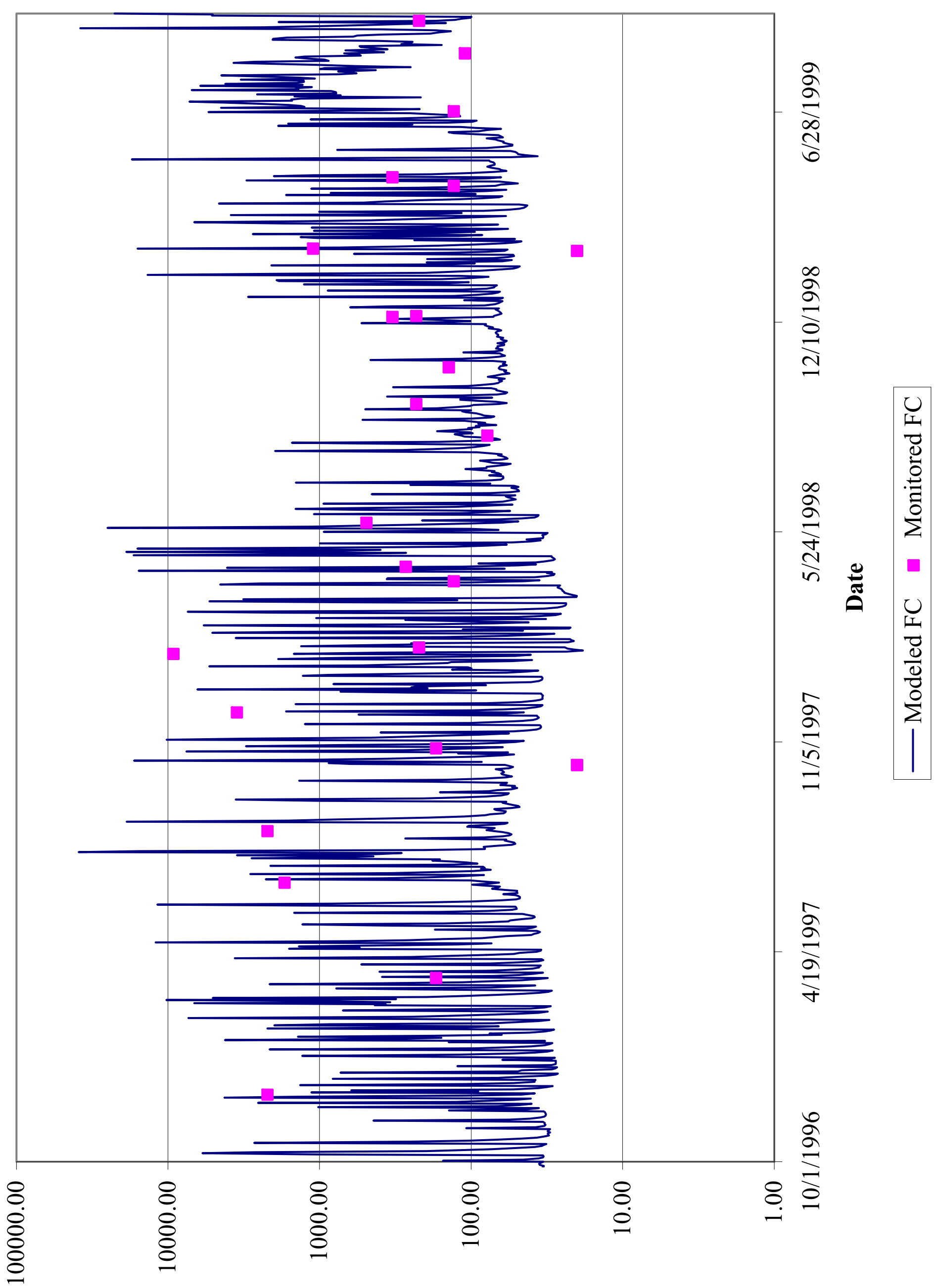

Figure 4.18 Quality calibration results for period 10/1/1996 to 9/30/1999 North River, subshed 15 VADEQ Station 2-NTH001.65.

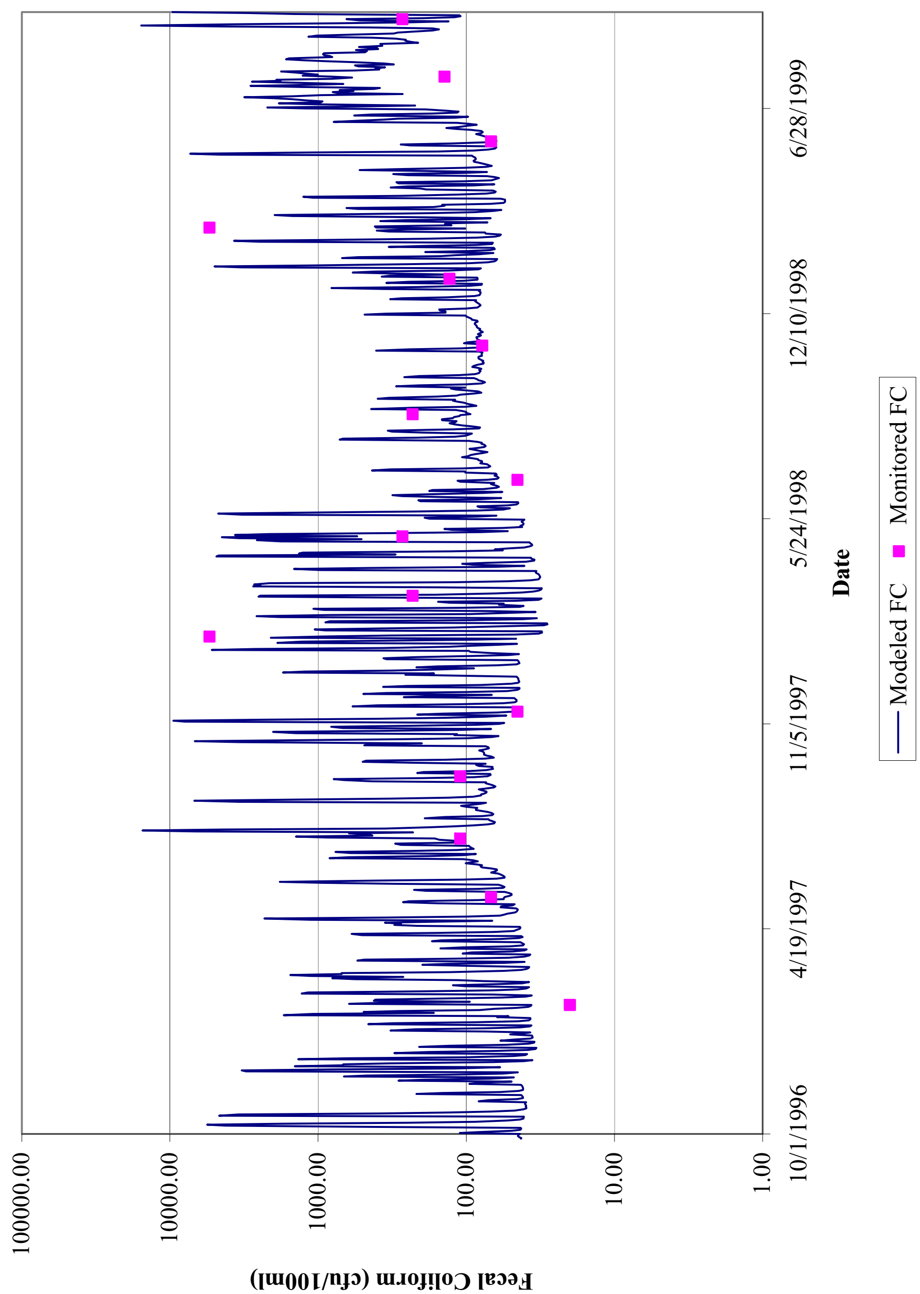

Figure 4.19 Quality calibration results for period 10/1/1996 to 9/30/1999 Slate River, subshed 10 VADEQ Station 2-SLT003.68.

Figure 4.20 Quality calibration results for period 10/1/1996 to 9/30/1999 Rock Island Creek, subshed 34 VADEQ Station 2-RKI003.40.

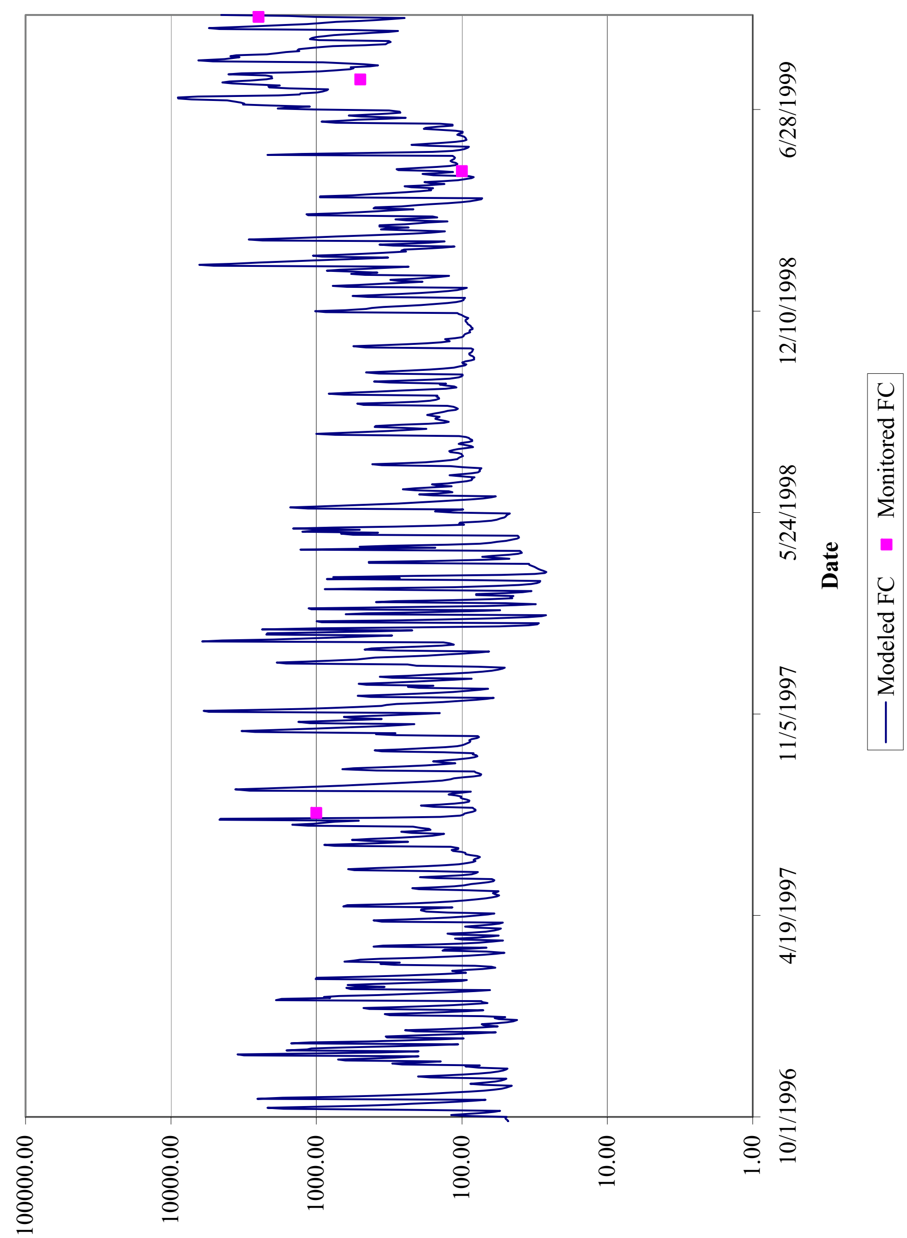

Figure 4.21 Quality calibration results for period 10/1/1996 to 9/30/1999 Ballinger Creek, subshed 37 VADEQ Station 2-BLR003.00.

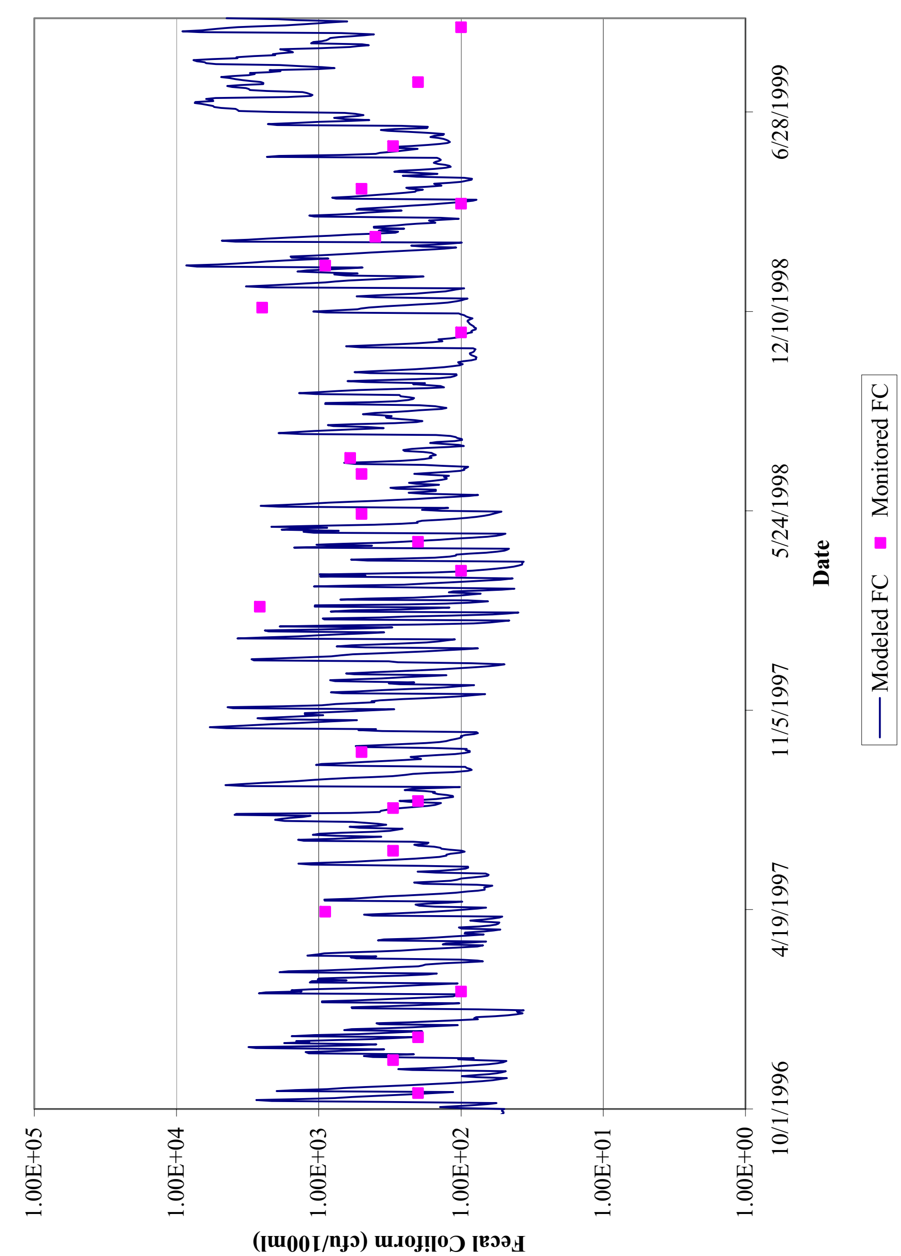

Figure 4.22 Quality calibration results for period 10/1/1996 to 9/30/1999 Totier Creek, downstream of the confluence of subsheds 39 and 41, VADEQ Station 2-TOT002.61.

Figure 4.23 Quality calibration results for period 10/1/1996 to 9/30/1999 Troublesome Creek, at the outlet of subshed 17, VADEQ Station 2-TBM000.80.

Careful inspection of graphical comparisons between continuous simulation results and observed points was the primary tool used to guide the calibration process. To provide a quantitative measure of the agreement between modeled and measured data while taking the inherent variability of fecal coliform concentrations into account, each observed value was compared with modeled concentrations in a 2-day window surrounding the observed data point. Standard error in each observation window was calculated as follows:

$$Standard\ Error = \frac{\sqrt{\dfrac{\sum_{i=1}^{n}\left(observed - modeled_i\right)^2}{(n-1)}}}{\sqrt{n}}$$

where

$$\begin{aligned} observed &= \text{an observed value of fecal coliform} \\ modeled_i &= \text{a modeled value in the 2 - day window surrounding the observation} \\ n &= \text{the number of modeled observations in the 2 - day window} \end{aligned}$$

This is a non-traditional use of standard error, applied here to offer a quantitative measure of model accuracy. In this context, standard error measures the variability of the sample mean of the modeled values about an instantaneous observed value. The use of limited instantaneous observed values to evaluate continuous data introduces error and, therefore, increases standard error. The mean of all standard errors for each station analyzed was calculated. Additionally, the maximum concentration values observed in the simulated data were compared with maximum values obtained from uncensored data (Chapter 2) and found to be at reasonable levels (Table 4.13). The standard errors in Table 4.13 range from a low of 16 to a high of 290. Even the highest value in this range can be considered quite reasonable when one takes into account the censoring of maximum values that is practiced in the taking of actual water quality samples. Thus, the standard errors calculated for these impairments are considered an indicator of good model performance.

Table 4.13 Results of analyses on calibration runs.

WQ Monitoring Station	Mean Standard Error (cfu/100ml)	Maximum Simulated Value (cfu/100ml)
2-FRY000.35	107	5,332
2-AUS001.12	16	8,598
2-TBM000.80	290	15,735
2-NTH001.65	102	38,762
2-SLT003.68	105	15,617
2-RKI003.40	165	10,472
2-BLR003.00	128	8,974
2-TOT002.61	41	9,106

Table 4.14 shows the predicted and observed values for instantaneous standard violation rate, and geometric mean for all impaired stream segments in the James River Tributaries in Albemarle and Buckingham Counties. For the majority of stations with a substantial sample population, differences between both the violation rates and geometric means are well within the range of reasonable model error.

Table 4.14 Comparison of modeled and observed geometric means.

Impairment	Reach ID	Station ID	Modeled Calibration Load Fecal Coliform 10/1/96 - 9/30/99			Monitored Fecal Coliform 10/1/96-9/30/99		
			n^1	Geometric Mean (cfu/100ml)	Exceedances of Instantaneous Standard	n^1	Geometric Mean (cfu/100ml)	Exceedances of Instantaneous Standard
Frisby Branch	2	2-FRY000.35	1095	184.56	17.99%	8	201.42	12.50%
Austin Creek	13	2-AUS001.12	1095	182.73	21.64%	11	115.30	27.27%
Troublesome Creek	17	2-TBM000.80	1095	84.87	12.79%	8	127.39	12.50%
North River	15	2-NTH001.65	1095	137.68	21.46%	24	301.87	29.17%
Slate River	10	2-SLT003.68	1095	146.36	19.82%	16	166.88	12.50%
Rock Island Creek	34	2-RKI003.40	1095	201.62	24.38%	23	221.27	26.09%
Ballinger Creek*	37	2-BLR003.00	1095	212.31	26.30%	4	594.6	75.00%
Totier Creek	Below the confluence of 39 & 41	2-TOT002.61	1095	305.60	37.35%	24	325.81	41.67%

*A quarterly monitoring station. Only four data points available during calibration period. Ballinger Creek's violation rate for the period of record is 34.78%.

The water quality validation was conducted for the time period from 10/01/1999 to 9/30/2001. The relationship between observed values and modeled values are shown in in Appendix C.

5. ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, permitted sources) and load allocations (LAs, nonpoint and sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (*e.g*., accuracy of wildlife populations). The definition is typically denoted by the expression:

TMDL = WLAs + LAs + MOS

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For fecal coliform bacteria, the TMDL is expressed in terms of colony forming units (or resulting concentration).

5.1 Incorporation of a Margin of Safety

In order to account for uncertainty in modeled output, a MOS was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. A margin of safety can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The intention of a MOS in the development of a fecal coliform TMDL is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of this TMDL. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will in fact succeed in meeting the water quality standard. Examples of the implicit MOS used in the development of this TMDL are:

- Allocating permitted point sources at the maximum allowable fecal coliform concentration,
- Selecting a modeling period that represented the critical hydrologic conditions in the watershed, and
- Modeling biosolids applications at the maximum allowable rate and fecal coliform concentration in all permitted fields.

5.2 Scenario Development

Allocation scenarios were modeled using HSPF. Existing conditions were adjusted until the water quality standard was attained. The TMDLs developed for the James River Tributaries in Albemarle and Buckingham Counties Study Area were based on the Virginia State Standard for *E. coli*. As detailed in Section 2.1, the *E. coli* standard states that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml, and that a maximum single sample concentration of *E. coli* shall not exceed 235 cfu/100 ml. According to the guidelines put forth by the VADEQ (VADEQ, 2003) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation (developed from a data set containing 493 paired data points):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc})$$

where C_{ec} is the concentration of *E. coli* in cfu/100 ml, and C_{fc} is the concentration of fecal coliform in cfu/100 ml.

Pollutant concentrations were modeled over the entire duration of a representative modeling period and pollutant loads were adjusted until the standard was met (Figures 5.1 through 5.16). The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the water quality target.

A growth/expansion load factor was included in each impairment to allow for new permits and/or expansion of existing ones. Permits for wastewater discharges require that bacteria be discharged at concentrations at or below the water quality standard. Future growth allocations for point sources were developed to be consistent with VADEQ guidance on new or expanding discharges (cite DEQ Guidance Memo 05-2011). Because permitted discharges are required to meet water quality standards for bacteria at the end of pipe, addition or expansion of these discharges is typically insignificant in causing or contributing to exceedences of the bacteria standard instream. To avoid having to modify developed TMDLs each time an insignificant increase in permitted point sources is made, these TMDLs were developed with a future growth allocation up to 1% of the TMDL. USEPA has determined that a less than 1% increase in a TMDL is insignificant.

5.2.1 Waste Load Allocations

There are eleven point sources currently permitted to discharge into the James River Tributaries in Albemarle and Buckingham Counties Study Area streams Figures 3.4 and 3.5 and Table 3.4. Eight are permitted for *E. coli* control. The allocation for the sources permitted for *E. coli* control is equivalent to their current permit levels (design discharge and 126 cfu/100 ml). Future growth in each watershed was accounted for by assuming a 500% growth in permit discharge for those watersheds with permitted discharge. For watersheds with no existing point sources such as Frisby Branch, Austin Creek, North River, Rock Island Creek, Ballinger Creek and Totier Creek, future growth in permitted point sources was accounted for as a 1% of the current TMDL in the watershed.

5.2.2 Load Allocations

Load allocations to nonpoint sources are divided into land-based loadings from land uses and directly applied loads in the stream (*e.g.,* livestock and wildlife). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads had their most significant impact during high-flow conditions, while direct deposition NPS had their most significant impact on low flow concentrations. The BST results for 2005-2006 confirmed the presence of human, livestock, pet, and wildlife contamination. Load reductions were performed by land use, as opposed to reducing sources, as it is considered that the majority of BMPs will be implemented by land use. Reductions on agricultural land uses (pasture and cropland) include reductions required for biosolids and imported poultry litter.

Allocation scenarios were run sequentially, beginning with headwater impairments, and then continuing with downstream impairments until all impairments were allocated to 0% exceedances of both standards. Tables 5.1 through 5.9 represent a portion of the scenarios developed to determine the TMDL for each impairment. Scenario 1 in each table describes a baseline scenario that corresponds to the existing conditions in the watershed. Model results indicate that human, livestock, and wildlife contributions are significant in all areas of the watershed. This is in agreement with the results of BST analysis presented in section 2.4.2.1.

Reduction scenarios exploring the role of anthropogenic sources in standards violations were explored first to determine the feasibility of meeting standards without wildlife reductions. In each table, scenario 2 attempts to determine the impact of non-anthropogenic sources (*i.e.,* wildlife), by exploring 100% reductions in all anthropogenic land-based and direct loads. In most cases, the model predicts that water quality standards will not be consistently met without reductions in wildlife loads. However, removal of all anthropogenic sources will result in a 10.5 or less percent violation of the instantaneous standard in all of the impaired segments. Therefore, delisting these segments is possible with no reductions to wildlife sources.

Since part of the TMDL development is the identification of phased implementation strategies, typical management scenarios were explored as well. Scenario 3 in each table contains reductions of 50% in all anthropogenic land-based loads and uncontrolled residential discharges, a 90% reduction in direct livestock deposition, and a 0% reduction in wildlife direct and land-based loading to the stream. This scenario corresponds to what is considered to be a reasonable scenario for a stage I implementation. The scenarios include several options that attempt to meet a 10.5% violation rate. This is an important milestone in phased implementation because it would allow delisting of the stream as impaired. Further scenarios in each table explore a range of management scenarios, leading to the final allocation scenario that contains the predicted reductions needed to meet both water quality standards.

5.2.2.1 Frisby Branch

Frisby Branch is located in the southwestern portion of Buckingham County and it flows in a northeasterly direction before the confluence with Grease Creek, which flows into the Slate River. The impaired section begins at the headwaters and continues downstream to the Grease Creek confluence (3.93 stream miles). The watershed is 85% forest and 6% pasture.

The total fecal coliform production per year in the watershed was modeled as 4.25E+14, with a fecal coliform density of 1.33E+11 cfu/acre. Major sources of fecal coliform bacteria in the watershed are hogs (72%), beef cattle (12%) and, wildlife (10%). The VADEQ monitoring stations, 2-FRY000.35 and 2-FRY003.00 had historical fecal coliform violation rates of 22% and 40% respectively.

Scenario 2 in Frisby Branch predicts that with removal of all anthropogenic sources there will be no violations of the instantaneous standard. Scenario 3 predicts that violations of the instantaneous standard will remain above 10.5% with moderate reductions in land-based anthropogenic sources, and a reduction of 90% of direct loads from livestock. Scenarios 4 through 7 explore increasing restrictions upon land-based and direct loads. Scenarios 8 through 10 represent three alternatives of reductions that would achieve an approximate 10.5% violation rate of the instantaneous standard. Scenario 13 shows the final allocation scenario for Frisby Branch, which requires 100% reductions from livestock and human direct sources and 99.3% reductions in anthropogenic non-point sources in order to obtain no violations of both standards.

Table 5.1 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 2, Frisby Branch.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	38.89	18.56
2	0	0	100	100	100	100	0.00	0.00
3	0	0	90	50	100	50	2.78	11.15
4	0	0	0	0	100	0	16.67	15.9
5	0	0	100	0	100	0	13.89	15.72
6	0	0	95	50	100	50	2.78	10.88
7	0	0	100	53	100	53	2.78	10.6
8	0	0	99	54	100	54	2.78	10.24
9	0	0	53.5	53.5	100	53.5	5.56	10.42
10	0	0	0	55	100	0	5.56	10.33
11	0	0	100	99	100	95	0.00	0.09
12	0	0	100	99.5	100	99	0.00	0.00
13	0	0	100	99.3	100	99.3	0.00	0.00

5.2.2.2 Austin Creek

Austin Creek is a tributary to the North River located in southwestern Buckingham County and flows in a northeasterly direction. Austin Creek is considered impaired for fecal coliform bacteria from it's headwaters to the confluence with the North River (6.14 stream miles). The watershed is 84% forest, 1% pasture, and approximately 12% in barren land uses.

The total fecal coliform production per year in the watershed was modeled as 2.38E+14, with a fecal coliform density of 5.03E+10 cfu/acre. Major sources of fecal coliform bacteria include hogs (65%), muskrat (9%), beef cattle (6%) and deer (5%). The total wildlife contribution to the fecal coliform load was estimated as 25%. The VADEQ monitoring station, 2-AUS001.12, has a historical fecal coliform violation rate of 20%.

Scenario 2 in Austin Creek predicts that with removal of all anthropogenic sources, violations of the instantaneous standard will still occur 5.58% of the time, with 0% violations of the geometric mean standard. This demonstrates that the wildlife load is a significant factor in the watershed. Scenario 3 explores another scenario, with 50% reductions in all anthropogenic land-based loads, and a reduction of 90% of direct loads from livestock, and predicts that violations of the instantaneous standard will remain above 10.5%. Scenarios 4, 5 and 6 explore increasing restrictions upon both land-based and direct loads, but demonstrate the need for reductions of wildlife contributions. Scenarios 7 through 9 represent three alternatives of reductions that would achieve a less than 10.5% violation rate of the instantaneous standard. Scenario 13 shows the final allocation scenario for Austin Creek, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in livestock land based sources, 99% reductions in human/pet land based sources, with 90% reductions necessary in wildlife land-based loads and 50% reduction of direct wildlife loads in order to obtain no violations.

Table 5.2 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 13, Austin Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	33.33	23.31
2	0	0	100	100	100	100	0.00	5.58
3	0	0	90	50	100	50	5.56	13.89
4	0	0	0	0	100	0	16.67	21.02
5	0	0	100	0	100	0	13.89	20.75
6	0	0	100	60	100	60	5.56	12.07
7	0	0	99	72	100	72	5.56	10.42
8	0	0	72.2	72.2	100	72.2	5.56	10.42
9	0	0	0	75	100	0	5.56	10.24
10	0	0	100	95	100	95	0.00	6.67
11	0	0	100	100	100	100	0.00	5.58
12	0	50	100	100	100	100	0.00	2.29
13	50	90	100	99	100	99	0.00	0.00

5.2.2.3 Upper Slate River

The Upper Slate River is located primarily in the southwestern portion of Buckingham County. The impaired section begins at the confluence with Grease Creek and continues downstream to the confluence with Walton Fork (13.28 stream miles). The watershed is 83% forest with 9% pasture.

The total fecal coliform production per year in the watershed was modeled as 1.28E+16, with a fecal coliform density of 1.85E+11 cfu/acre. Major sources of fecal coliform bacteria are hogs (49%), broilers (26%) and beef cattle (12%). The total wildlife contribution to the fecal coliform load is estimated as 8%. The VADEQ monitoring stations, 2-SLT024.72 and 2-SLT030.19, have historical fecal coliform violations rate of 30% and 50% respectively.

Scenario 2 for the Upper Slate River shows that with removal of all anthropogenic sources, violations of the instantaneous standard will still occur 2.29% of the time, with 0% violations of the geometric mean standard. Scenario 3 predicts that violations of the instantaneous standard will remain above a 10.5% violation rate with 50% reductions in land-based anthropogenic sources, and a reduction of 90% of direct loads from livestock. Scenarios 4 and 5 explore increasingly stringent restrictions upon land-based and direct loads and demonstrate the need for reductions in wildlife sources to attain final compliance with the standards. Scenarios 6 through 8 represent three alternatives of reductions that would achieve an approximate 10.5% violation of the instantaneous standard. Scenario 12 shows the final allocation scenario for the Upper Slate River, which requires 100% reductions in all anthropogenic direct sources, 99.5% reductions in land based agricultural loads, 99% reductions in residential and urban land-based loads and a 99% reduction in wildlife land-based loads and direct loads in order to obtain no violations of the standards.

Table 5.3 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 5, Upper Slate River.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	27.78	20.11
2	0	0	100	100	100	100	0.00	2.29
3	0	0	90	50	100	50	0.00	13.71
4	0	0	0	0	100	0	5.56	19.29
5	0	0	100	0	100	0	5.56	19.2
6	0	0	99	55	100	55	0.00	10.33
7	0	0	57	57	100	57	0.00	10.42
8	0	0	0	60	100	0	0.00	10.42
9	0	0	100	90	100	90	0.00	8.23
10	99	99	100	99.5	100	99	0.00	6.31
11	0	0	100	100	100	100	0.00	2.29
10	50	50	100	99	100	99	0.00	0.09
12	99	99	100	99.5	100	99	0.00	0.00

Note scenarios 6 through 8 were run with upstream impairments at a similar 10.5% violation rate and scenarios 9 through 12 were run with upstream impairments at a 10.5% violation rate rather than a 0% violation rate.

5.2.2.4 Troublesome Creek

Troublesome Creek is located in the south central portion of Buckingham County and flows in a northerly direction before the confluence with the Slate River. The impaired section begins at the Troublesome Creek Reservoir and continues downstream to the confluence with the Slate River (0.95 stream miles). The watershed is 76% forested with 11% in pasture and 2% in residential.

Total fecal coliform production per year in the watershed was modeled as 2.07E+15, with a fecal coliform density of 4.81E+11 cfu/acre. Major sources of fecal coliform bacteria are poultry (69%), hogs (18%) and beef cattle (6%). The total wildlife contribution to the fecal coliform load is estimated as 3%. The VADEQ monitoring station, 2-TBM000.80 has a historical fecal coliform violation rate of 20%.

Scenario 2 for Troublesome Creek shows that with removal of all anthropogenic sources, there will be no violations of either the instantaneous or geometric mean standard. Scenario 3 predicts that violations of the instantaneous standard will fall below a 10.5% violation rate with 50% reductions in land-based anthropogenic sources, and a reduction of 90% of direct loads from livestock. Scenarios 6 through 8 represent three alternatives of reductions necessary to attain a less than 10.5% violation rate of the instantaneous standard. Scenario 13 shows the final allocation scenario for Troublesome Creek, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in non-point anthropogenic loads to agricultural land and 80% reductions in non-point anthropogenic loads to residential and urban land-based loads in order to obtain no violations of water quality standards.

Table 5.4 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 17, Troublesome Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	0.00	11.97
2	0	0	100	100	100	100	0.00	0.00
3	0	0	90	50	100	50	0.00	6.95
4	0	0	0	0	100	0	0.00	11.43
5	0	0	100	0	100	0	0.00	11.06
6	0	0	99	7.5	100	7.5	0.00	10.42
7	0	0	8	8	100	8	0.00	10.33
8	0	0	0	15	100	0	0.00	10.33
9	0	0	100	20	100	20	0.00	8.87
10	0	0	100	95	100	95	0.00	1.37
11	0	0	100	97	100	97	0.00	0.73
12	0	0	100	99	100	75	0.00	0.09
13	0	0	100	99	100	80	0.00	0.00

5.2.2.5 North River

North River is located in the southwestern portion of Buckingham County and it flows in a northeasterly direction before its confluence with the Slate River. The impaired segment begins at the confluence with Meadow Creek and continues downstream to the confluence with the Slate River (8.44 stream miles). The watershed is 81% forested with 9% in pasture and 6% barren.

Total fecal coliform production per year in the watershed was modeled as 4.20E+15, with a fecal coliform density of 1.90E+11 cfu/acre. Major sources of fecal coliform bacteria include hogs (75%) and beef (12%). The total wildlife contribution to the fecal coliform load is estimated as 8%. The long term VADEQ monitoring station, 2-NTH001.65, has a historical fecal coliform violation rate of 24%. An additional monitoring station added in 1997, 2-NTH003.88 has a historical fecal coliform violation rate of 70%.

Scenario 2 for the North River shows that with removal of all anthropogenic sources, violations of the instantaneous standard will still occur 2.29% of the time, with 0.00% violations of the geometric mean standard. Scenario 3 predicts that violations of the instantaneous standard will remain above 10.5% with moderate reductions in land-based anthropogenic sources, and a reduction of 90% of direct loads from livestock. Scenarios 4 and 5 explore greater restrictions upon land-based and direct loads, and further demonstrate the need for reductions of wildlife contributions. Scenarios 6 through 8 represent three alternatives of reductions to achieve a less than 10.5% violation rate of the instantaneous standard. Scenario 13 shows the final allocation scenario for the North River, which requires 100% reductions in all anthropogenic direct sources, 99.5% reductions in non-point agricultural and residential and urban land-based loads, and a 97% reduction in wildlife land-based loads and direct loads in order to obtain no violations of either standard.

Table 5.5 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 16, North River.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	19.44	19.93
2	0	0	100	100	100	100	0.00	2.29
3	0	0	90	50	100	50	2.78	15.17
4	0	0	0	0	100	0	5.56	19.47
5	0	0	100	0	100	0	5.56	19.47
6	0	0	99	76	100	76	0.00	10.42
7	0	0	76	76	100	76	0.00	10.42
8	0	0	0	83	100	0	0.00	10.42
9	0	0	100	80	100	80	0.00	7.31
10	0	0	100	90	100	90	0.00	5.48
11	0	0	100	100	100	100	0.00	2.1
12	90	90	100	99	100	99	0.00	0.46
13	97	97	100	99.5	100	99.5	0.00	0.00

Note scenarios 6 through 8 were run with upstream impairments at a similar 10.5% violation rate and scenarios 9 through 13 were run with upstream impairments at a 10.5% violation rate rather than a 0% violation rate.

5.2.2.6 Lower Slate River

The Lower Slate River is located in the northeastern portion of Buckingham County and flows northeast before its confluence with the James River. The impaired section begins at the Sharps Creek confluence and continues downstream to the James River confluence (7.12 stream miles). The watershed is 82% forested with 9% in pasture.

Total fecal coliform production per year in the watershed was modeled as 2.04E+16, with a fecal coliform density of 1.30E+11 cfu/acre. Major sources of fecal coliform bacteria include hogs (43%), poultry (21%) and beef cattle (18%). The total wildlife contribution to the fecal coliform load is estimated as 11%. The long term VADEQ monitoring station, 2-SLT003.68, has a historical fecal coliform violation rate of 12%.

Scenario 2 for the Lower Slate River shows that with removal of all anthropogenic sources, violations of the instantaneous standard will still occur 1.46% of the time, with 0.00% violations of the geometric mean standard. Scenario 3 predicts that violations of the instantaneous standard will remain above the 10.5% violation rate with moderate reductions in land-based anthropogenic sources, and a reduction of 100% of direct loads from livestock. Scenarios 4 and 5 explore greater restrictions upon land-based and direct loads, and further demonstrate the need for reductions of wildlife contributions. Scenarios 6 through 8 represent three alternatives of reductions to achieve a violation rate less than 10.5% of the instantaneous standard. Scenario 12 shows the final allocation scenario for the Lower Slate River, which requires 100% reductions in all anthropogenic direct sources and a 60% reduction in wildlife land-based loads and direct loads in order to obtain no violations of either standard.

Table 5.6 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 12, Lower Slate River.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	19.44	20.02
2	0	0	100	100	100	100	0.00	1.46
3	0	0	90	50	100	50	0.00	15.17
4	0	0	0	0	100	0	5.56	18.19
5	0	0	100	0	100	0	5.56	17.46
6	0	0	99	39.5	100	39.5	0.00	10.33
7	0	0	40	40	100	40	0.00	10.33
8	0	0	0	45	100	0	0.00	10.24
9	0	0	100	50	100	50	0.00	9.60
10	0	0	100	99	100	99	0.00	7.22
11	55	55	100	99	100	99	0.00	0.09
12	60	60	100	99	100	99	0.00	0.00

Note scenarios 6 through 8 were run with upstream impairments at a similar 10.5% violation rate and scenarios 9 through 12 were run with upstream impairments at a 10.5% violation rate rather than a 0% violation rate.

5.2.2.7 Rock Island Creek

Rock Island Creek is located in the northern portion of Buckingham County. It flows north before its confluence with the James River. The impaired section begins at the headwaters and continues downstream to the James River confluence (8.84 stream miles). The watershed is 88% forested with 5% pasture and 4% barren.

Total fecal coliform production per year in the watershed was modeled as 4.46E+14, with a fecal coliform density of 3.42E+10 cfu/acre. Major sources of fecal coliform bacteria include beef cattle (43%), raccoon (18%) and muskrat (14%). The total wildlife contribution to the fecal coliform load is estimated as 40%. The long term VADEQ monitoring station, 2-RKI003.40, has a historical fecal coliform violation rate of 21%.

Scenario 2 for Rock Island Creek shows that with removal of all anthropogenic sources, violations of the instantaneous standard will occur 2.74% of the time, with 0.00% violations of the geometric mean standard. Scenario 3 predicts that violations of the instantaneous standard will remain above 10.5% with moderate reductions in land-based anthropogenic sources, and a reduction of 100% of direct loads from livestock. Scenarios 4 and 5 explore more stringent restrictions upon land-based and direct loads and further demonstrate the need for reductions of wildlife contributions. Scenarios 6 through 8 represent three alternatives of reductions to achieve a violation rate less than 10.5% of the instantaneous standard. Scenario 12 shows the final allocation scenario for Rock Island Creek, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in non-point anthropogenic loads, and 84% reduction in wildlife direct loads and land-based loads in order to obtain no violations of the standards.

Table 5.7 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 35, Rock Island Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	33.33	20.57
2	0	0	100	100	100	100	0.00	2.74
3	0	0	90	50	100	50	8.33	12.43
4	0	0	0	0	100	0	13.89	17.46
5	0	0	100	0	100	0	11.11	17.00
6	0	0	99	68.5	100	68.5	0.00	10.33
7	0	0	69	69	100	69	0.00	10.24
8	0	0	0	94	100	0	0	10.42
9	0	0	100	80	100	80	5.56	9.32
10	0	0	100	99	100	99	0.00	6.58
11	80	80	100	99	100	99	0.00	0.27
12	84	84	100	99	100	99	0.00	0.00

5.2.2.8 Ballinger Creek

Ballinger Creek is located in the southern tip of Albemarle County and flows south before its confluence with the James River. The impaired section stretches from the headwaters to the confluence at the James River (9.82 stream miles). The watershed is 72% forest with 22% pasture and 2% in cropland.

Total fecal coliform production per year in the watershed was modeled as 6.93E+14, with a fecal coliform density of 6.20E+10 cfu/acre. Major sources of fecal coliform bacteria include beef cattle (39%), horse (21%) and raccoon (10%). The total wildlife contribution to the fecal coliform load is estimated as 23%. The long term VADEQ monitoring station, 2-BLR003.00, has a historical fecal coliform violation rate of 35%.

Scenario 2 for Ballinger Creek shows that with removal of all anthropogenic sources, violations of the instantaneous standard will occur 0.91% of the time, with 0.00% violations of the geometric mean standard. Scenario 3 predicts that violations of the instantaneous standard will remain just above the 10.5% instantaneous standard violation rate with moderate reductions in land-based anthropogenic sources, and a reduction of 100% of direct loads from livestock. Scenarios 4, 5 and 6 explore more stringent restrictions upon land-based and direct loads and further demonstrate the need for reductions of wildlife contributions. Scenarios 7 through 9 represent three alternatives of reductions to achieve a violation rate less than 10.5% of the instantaneous standard. Scenario 12 shows the final allocation scenario for Ballinger Creek, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in non-point anthropogenic loads and 51% reduction in wildlife direct loads and land-based loads in order to obtain no violations of the standards.

Table 5.8 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 38, Ballinger Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	36.11	21.57
2	0	0	100	100	100	100	0.00	0.91
3	0	0	90	50	100	50	5.56	11.79
4	0	0	0	0	100	0	22.22	19.74
5	0	0	100	0	100	0	22.22	19.2
6	0	0	100	50	100	50	8.33	11.7
7	0	0	99	52	100	52	2.78	10.42
8	0	0	53.2	53.2	100	53.2	2.78	10.33
9	0	0	0	75	100	0	0.00	7.4
10	0	0	100	60	100	60	5.56	9.14
11	50	50	100	99	100	99	0.00	0.18
12	51	51	100	99	100	99	0.00	0.00

5.2.2.9 Totier Creek

Totier Creek is located in the southern tip of Albemarle County and flows south before its confluence with the James River. The impaired section stretches from the headwaters to the confluence at the James River (11.29 stream miles). The watershed is 56% forest with 35% pasture and 3% in cropland.

Total fecal coliform production per year in the watershed was modeled as 1.21E+15, with a fecal coliform density of 6.25E+10 cfu/acre. Major sources of fecal coliform bacteria include horse (32%) beef cattle (21%) and raccoon (10%). The total wildlife contribution to the fecal coliform load is estimated as 23%. The long term VADEQ monitoring station, 2-TOT002.61, has a historical fecal coliform violation rate of 25%.

Scenario 2 for Totier Creek shows that with removal of all anthropogenic sources, violations of the instantaneous standard will occur 0.90% of the time, with 0.00% violations of the geometric mean standard. Scenario 3 predicts that the violation rate will remain above the 10.5% of the instantaneous standard with moderate reductions in land-based anthropogenic sources, and a reduction of 90% of direct loads from livestock. Scenarios 4, 5, 6 and 7 explore more stringent restrictions upon land-based and direct loads and further demonstrate the need for reductions of wildlife contributions. Scenarios 8 through 10 represent three alternatives of reductions to achieve an approximate 10.5% violation rate of the instantaneous standard. Scenario 12 shows the final allocation scenario for Ballinger Creek, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in non-point anthropogenic loads and 1% reduction in wildlife direct loads and land-based loads in order to obtain no violations of the standards.

Table 5.9 Allocation scenarios for bacterial concentration with current loading estimates in model segment 39, Totier Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential/ Commercial Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	50	26.14
2	0	0	100	100	100	100	0.00	0.09
3	0	0	90	50	100	50	22.22	15.54
4	0	0	0	0	100	0	38.89	24.77
5	0	0	100	0	100	0	36.11	24.59
6	0	0	100	40	100	40	22.22	17.18
7	0	0	100	65	100	65	11.11	11.7
8	0	0	99	70	100	70	8.33	10.42
9	0	0	70.5	70.5	100	70.5	8.33	10.33
10	0	0	0	80	100	0	19.44	10.42
11	0	0	100	99	100	99	0.00	0.09
12	1	1	100	99	100	99	0.00	0.00

Figures 5.1 through 5.9 show the monthly instantaneous values for existing and allocated conditions for all impairments in the James River Tributaries in Albemarle and Buckingham Counties Study Area. These graphs show allocated conditions in black, with existing conditions overlaid in gray.

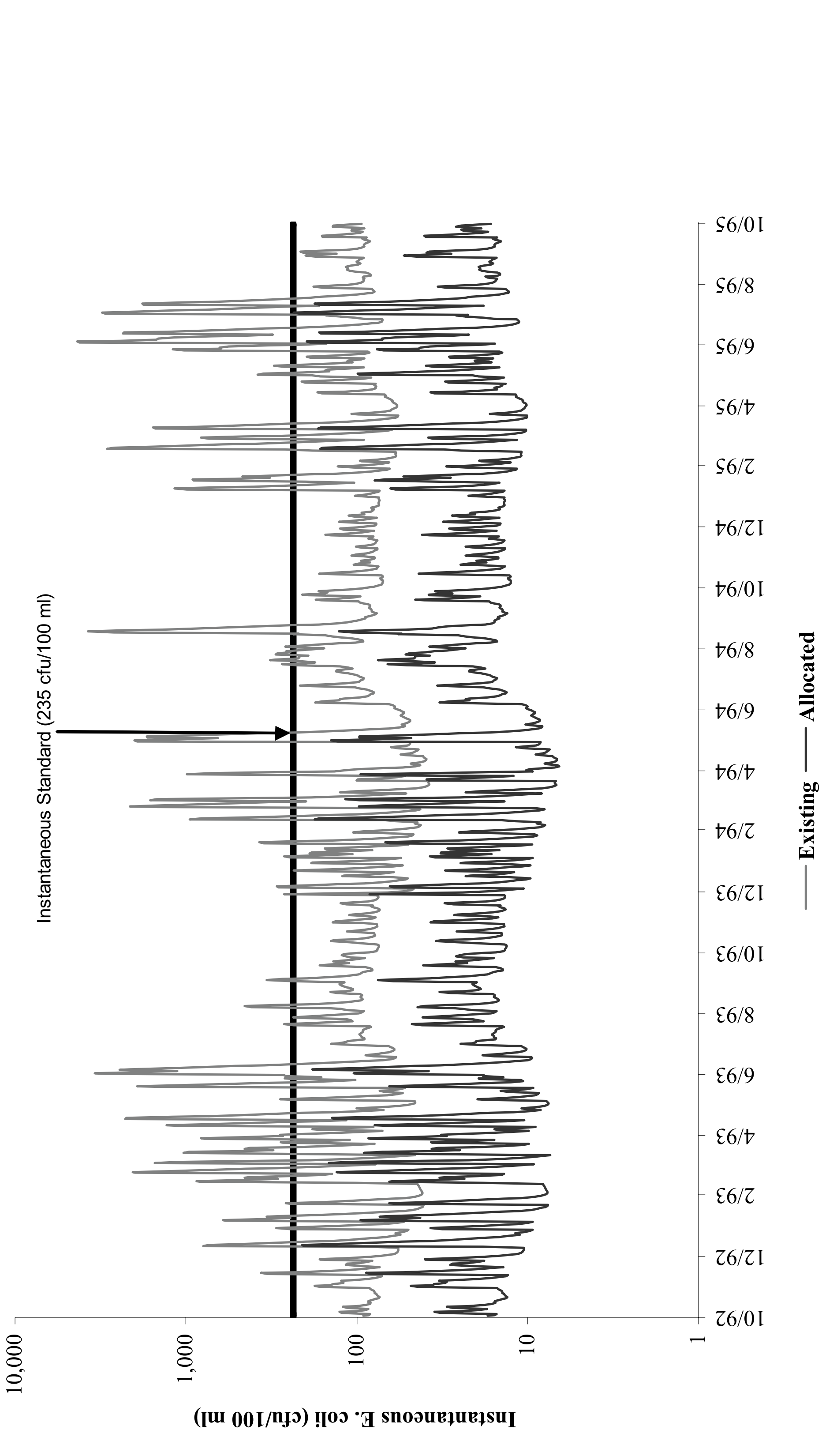

Figure 5.1 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 2, Frisby Branch impairment.

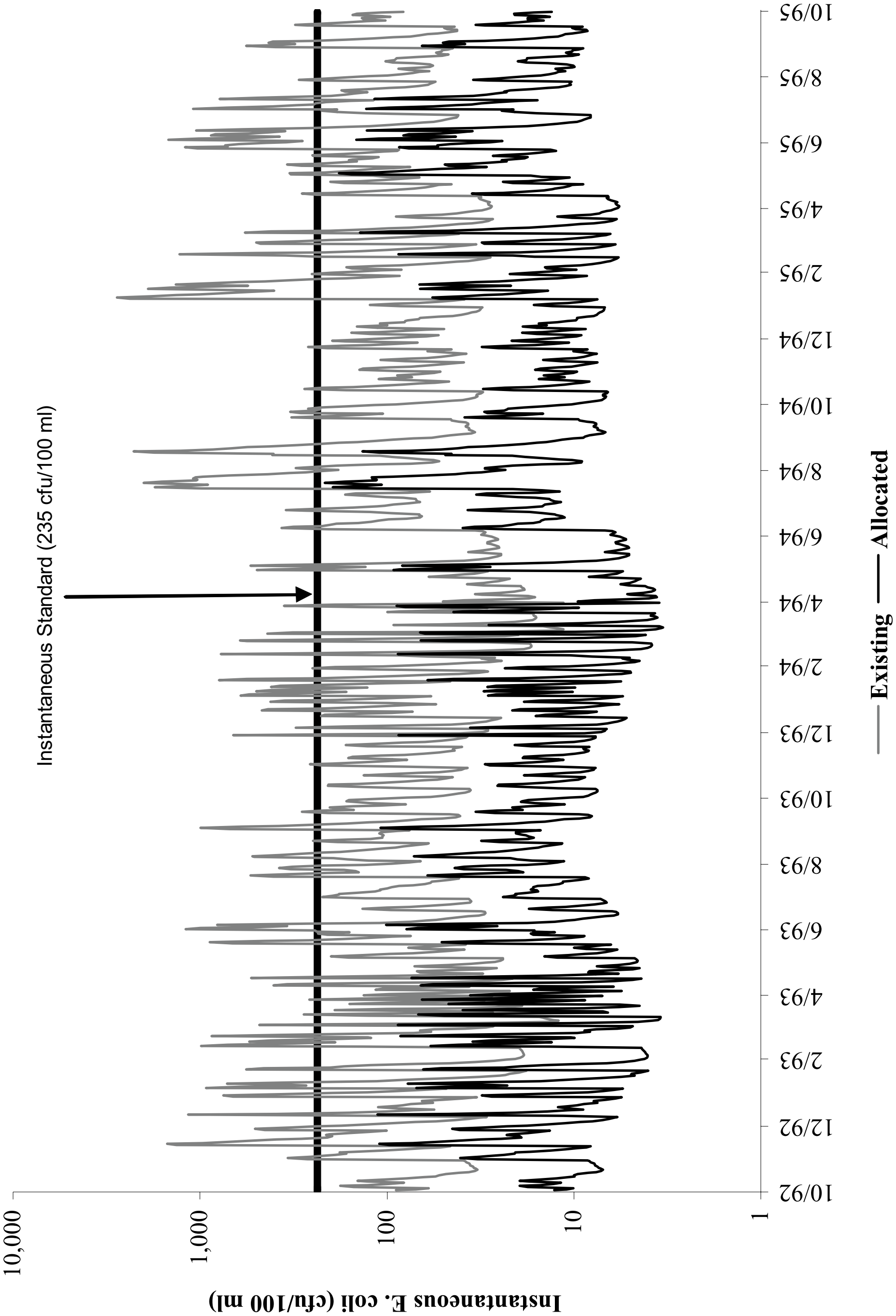

Figure 5.2 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 13, Austin Creek impairment.

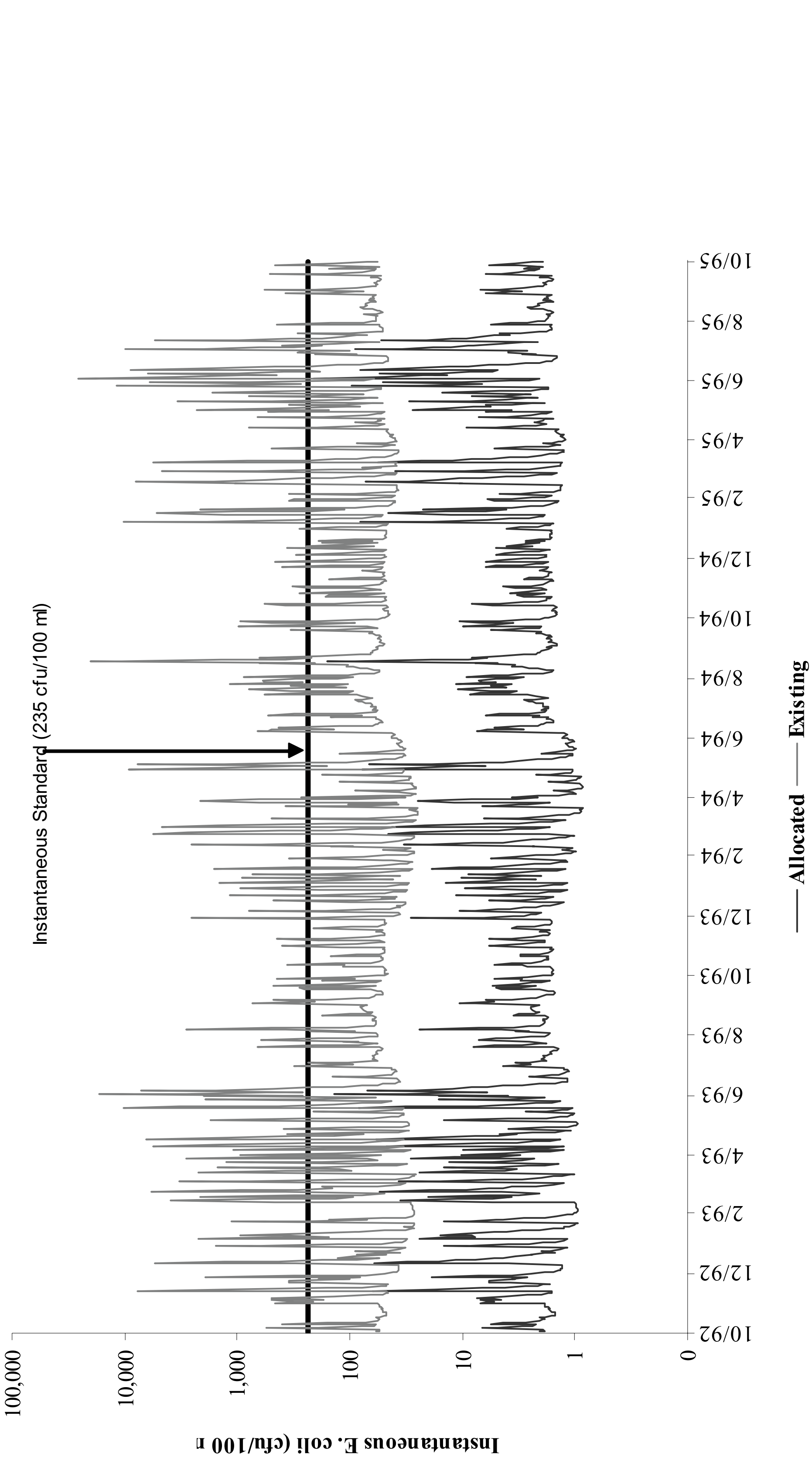

Figure 5.3 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 5, Upper Slate River impairment.

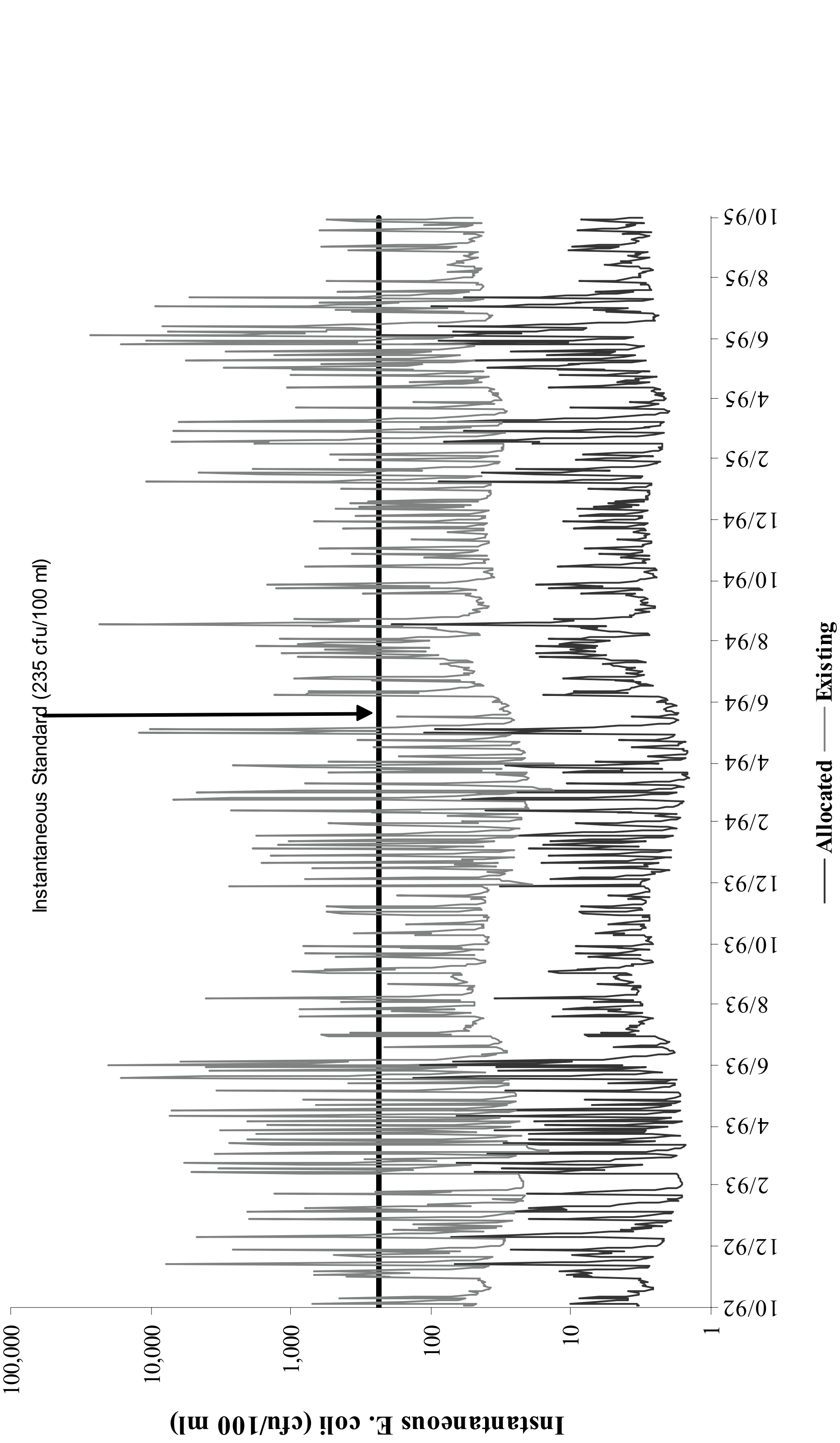

Figure 5.4 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 16, North River impairment.

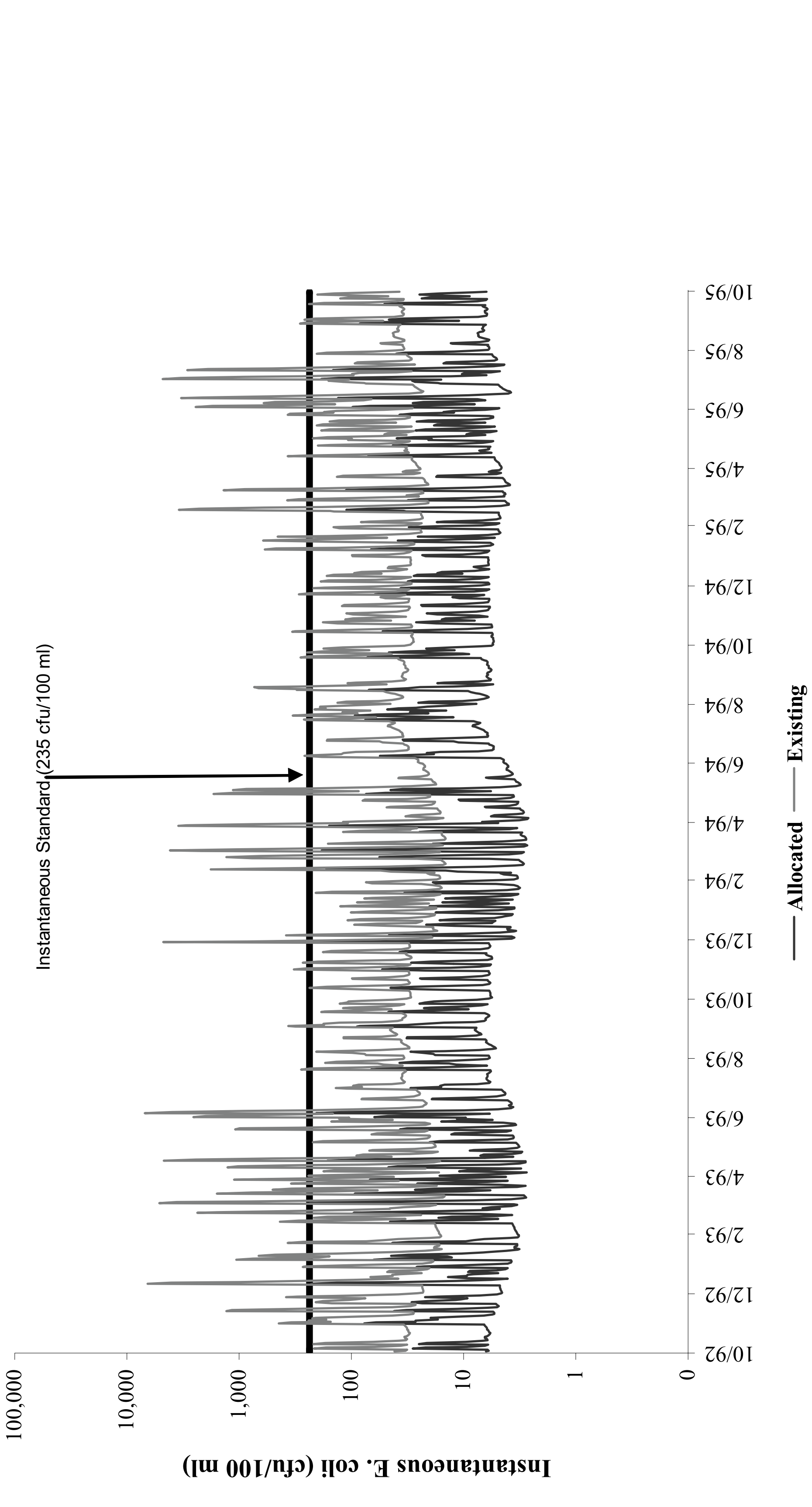

Figure 5.5 Existing and allocation scenarios of *E. coli* concentrations in model segment 4 subwatershed 17, Troublesome Branch impairment.

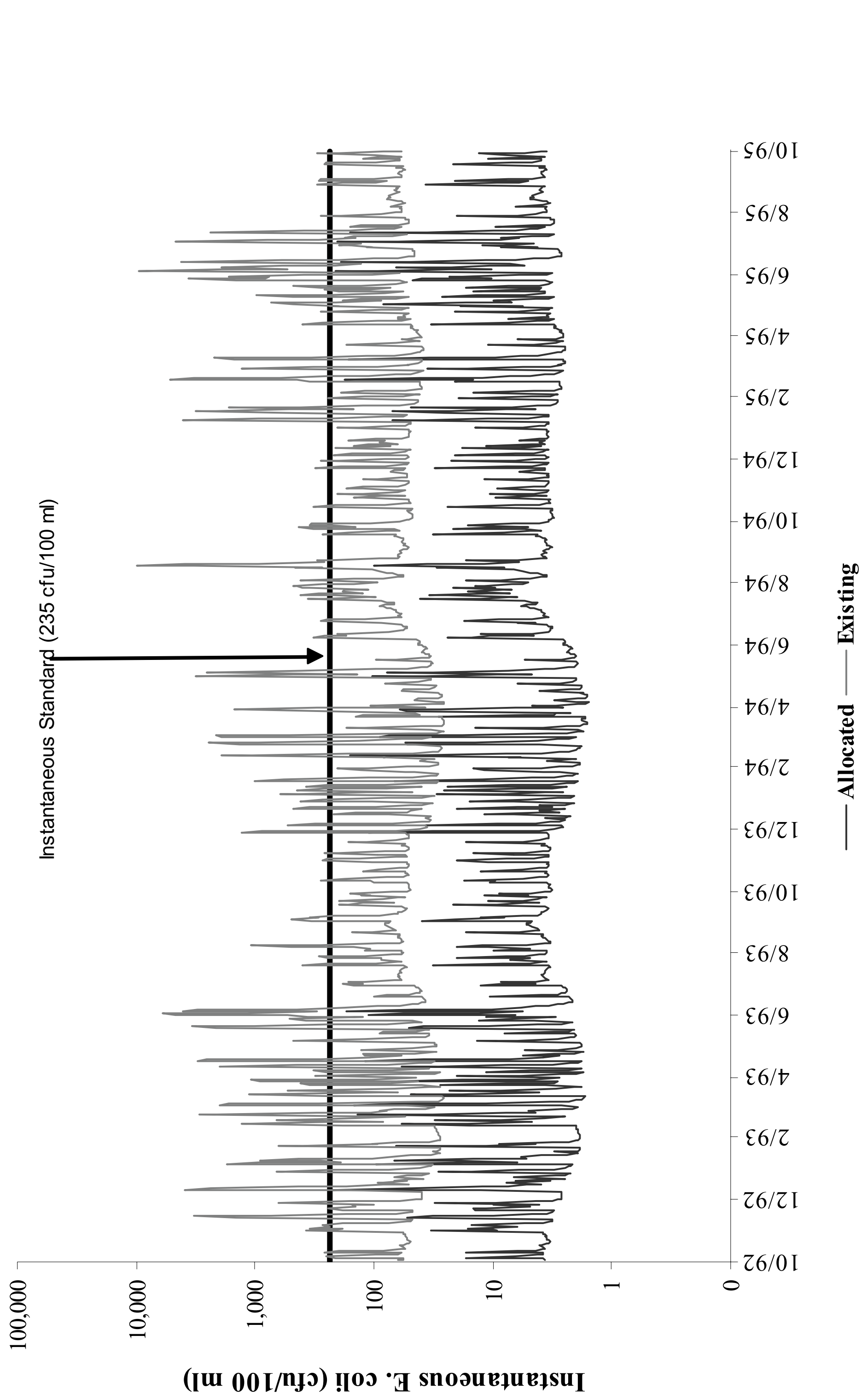

Figure 5.6 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 10, Lower Slate River impairment.

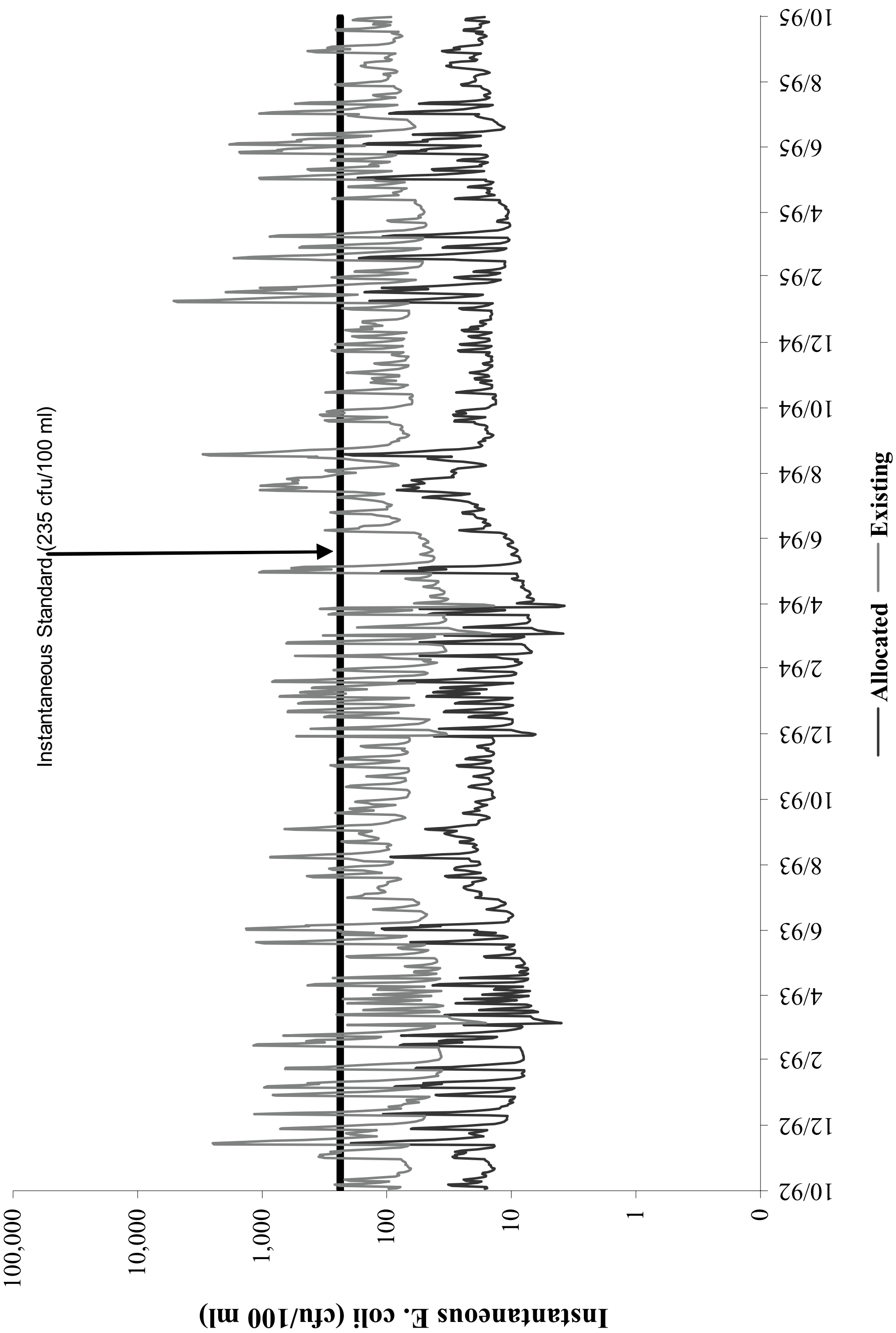

Figure 5.7 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 34, Rock Island Creek impairment.

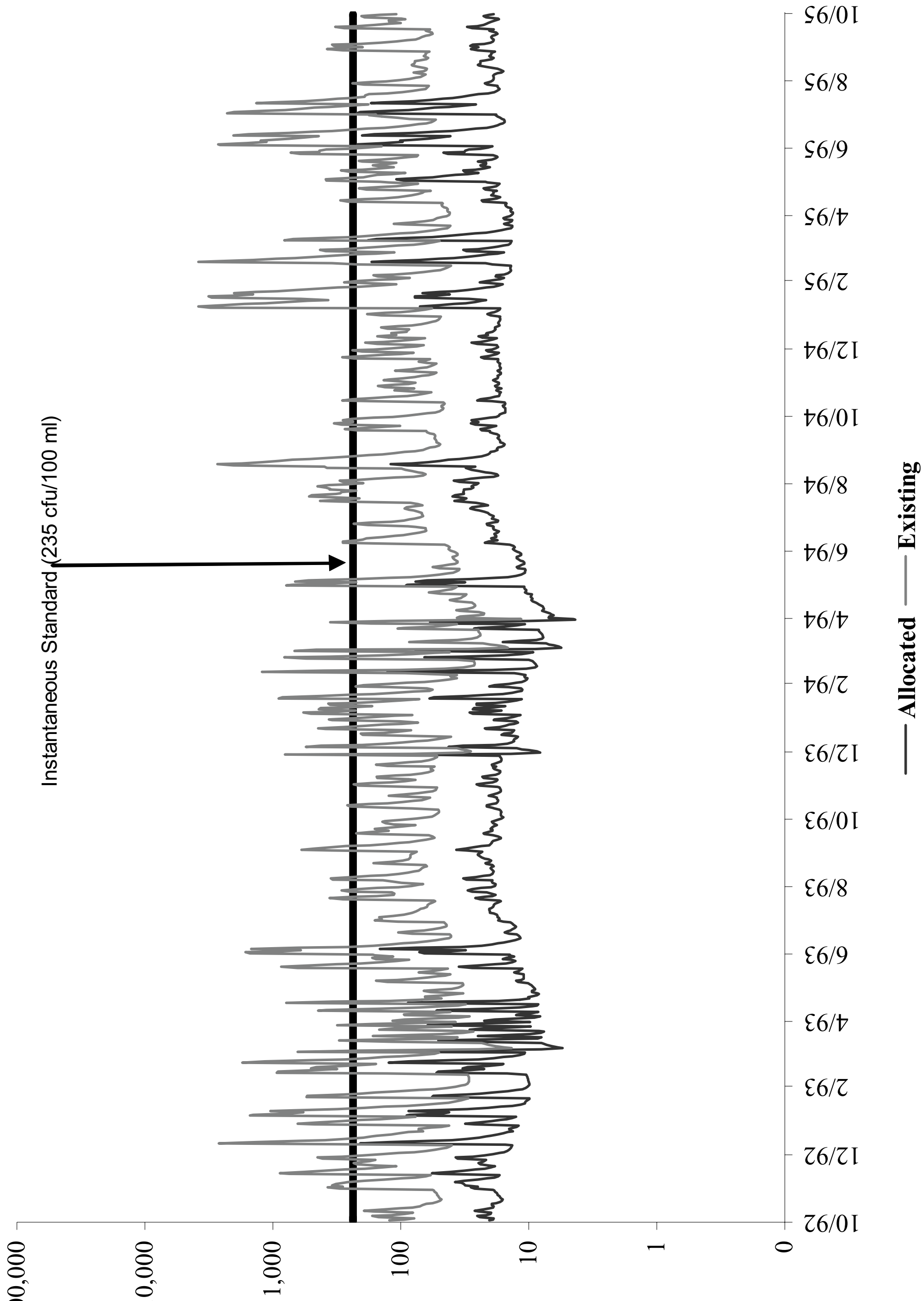

Figure 5.8 Existing and allocation scenarios of *E. coli* concentrations in model segment 6 subwatershed 37, Ballinger Creek impairment.

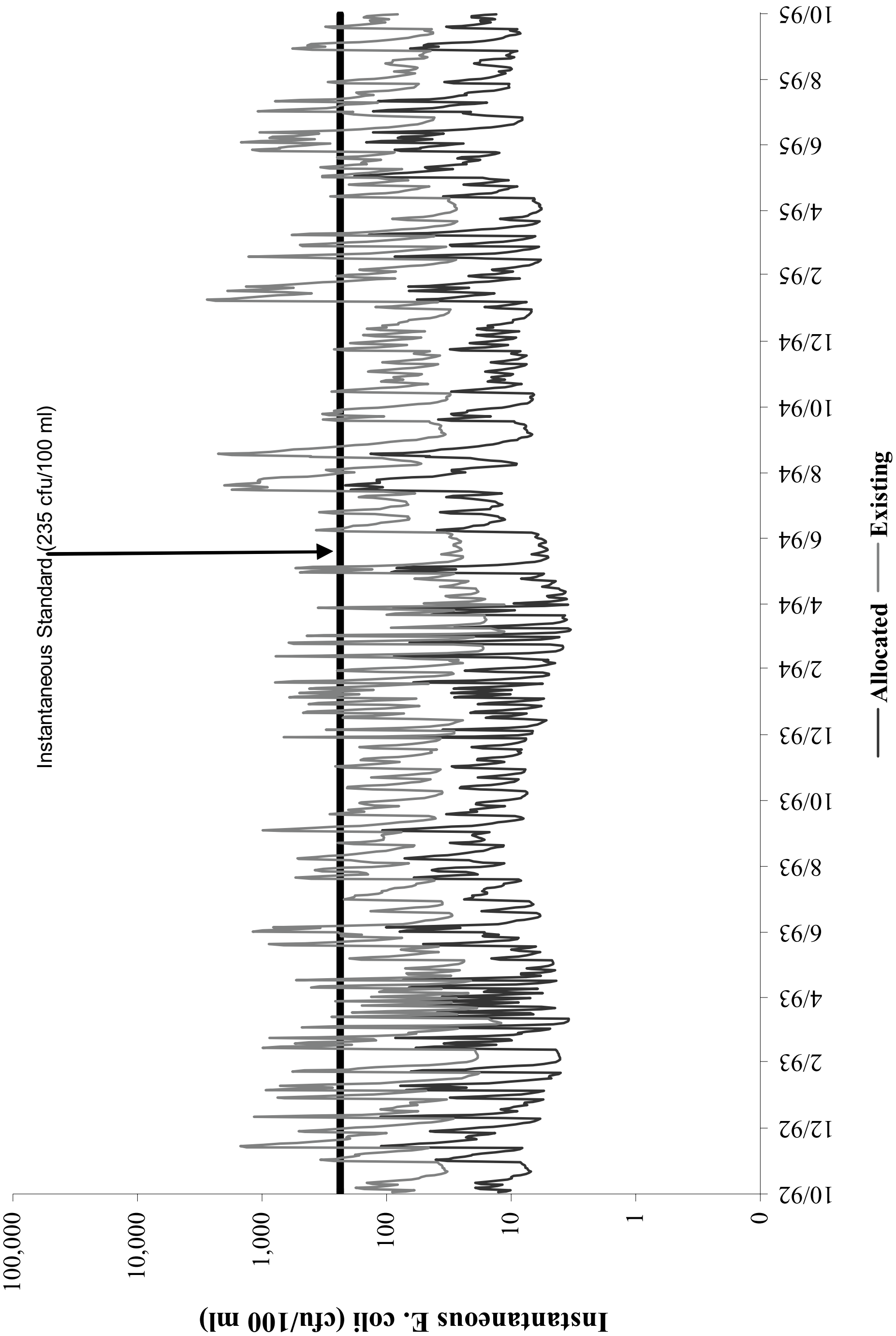

Figure 5.9 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 39, Totier Creek impairment.

Figures 5.10 through 5.18 show the monthly geometric mean concentrations for existing and allocated conditions for all impairments in the James River Tributaries in Albemarle and Buckingham Counties Study Area. These graphs show existing conditions in gray, with allocated conditions overlaid in black. The monthly geometric mean is calculated from the daily average *E. coli* concentration, predicted by the water quality model, and is grouped by calendar month.

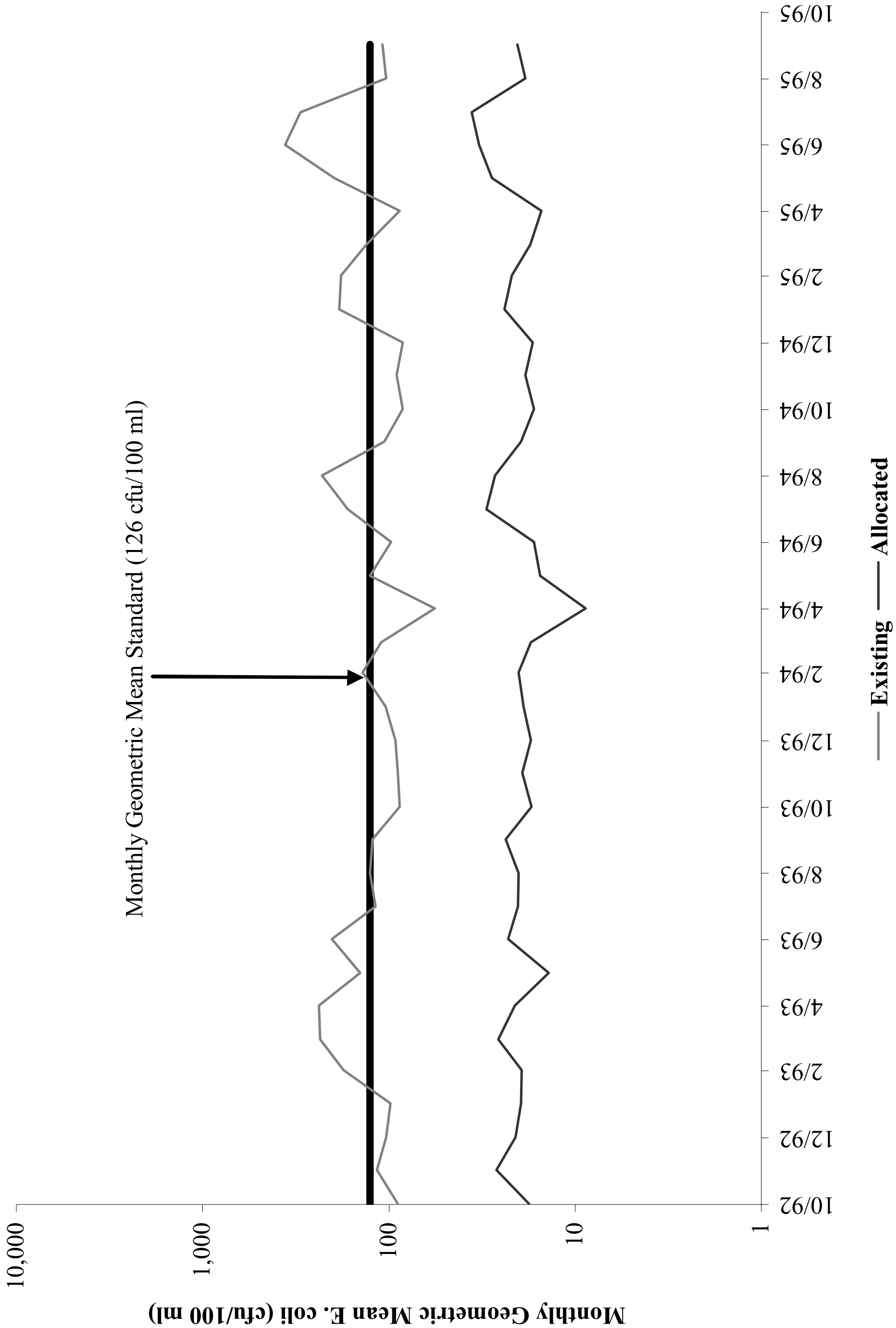

Figure 5.10 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 2, Frisby Branch impairment.

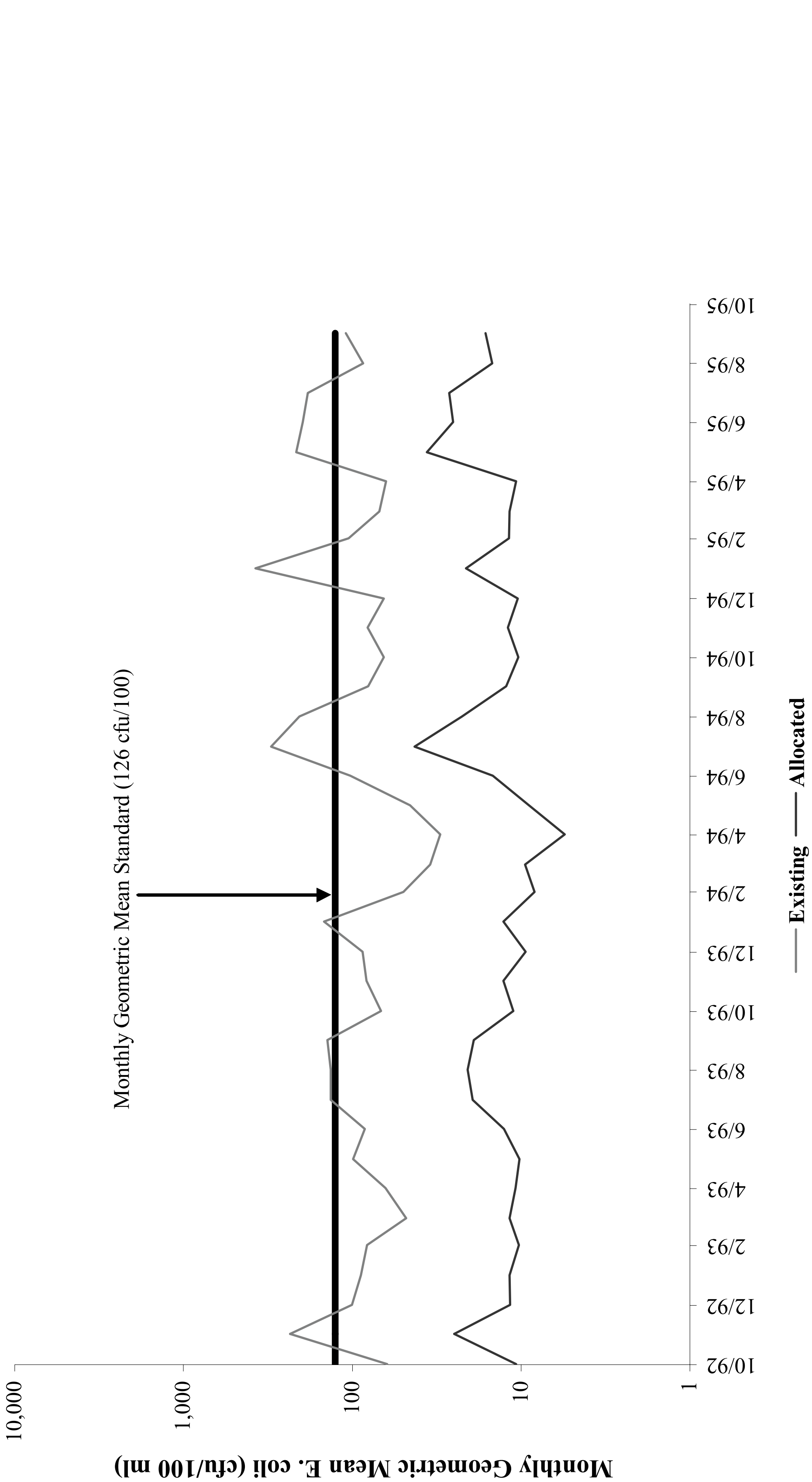

Figure 5.11 Existing and allocation scenarios of *E. coli* concentrations in model segment 1 subwatershed 13, Austin Creek impairment.

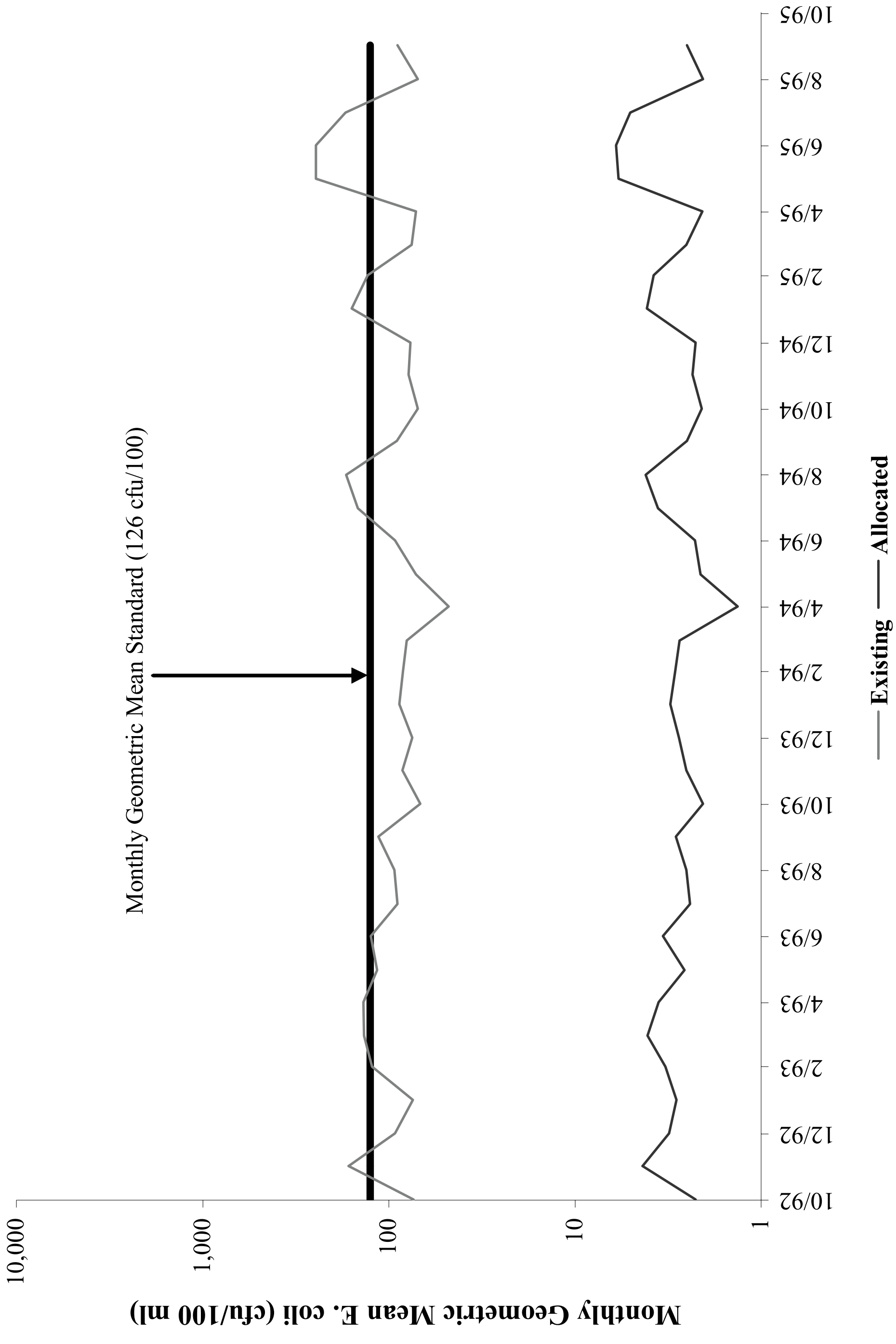

Figure 5.12 Existing and allocation scenarios of *E. coli* concentrations in model segment 1 subwatershed 5, Upper Slate River impairment.

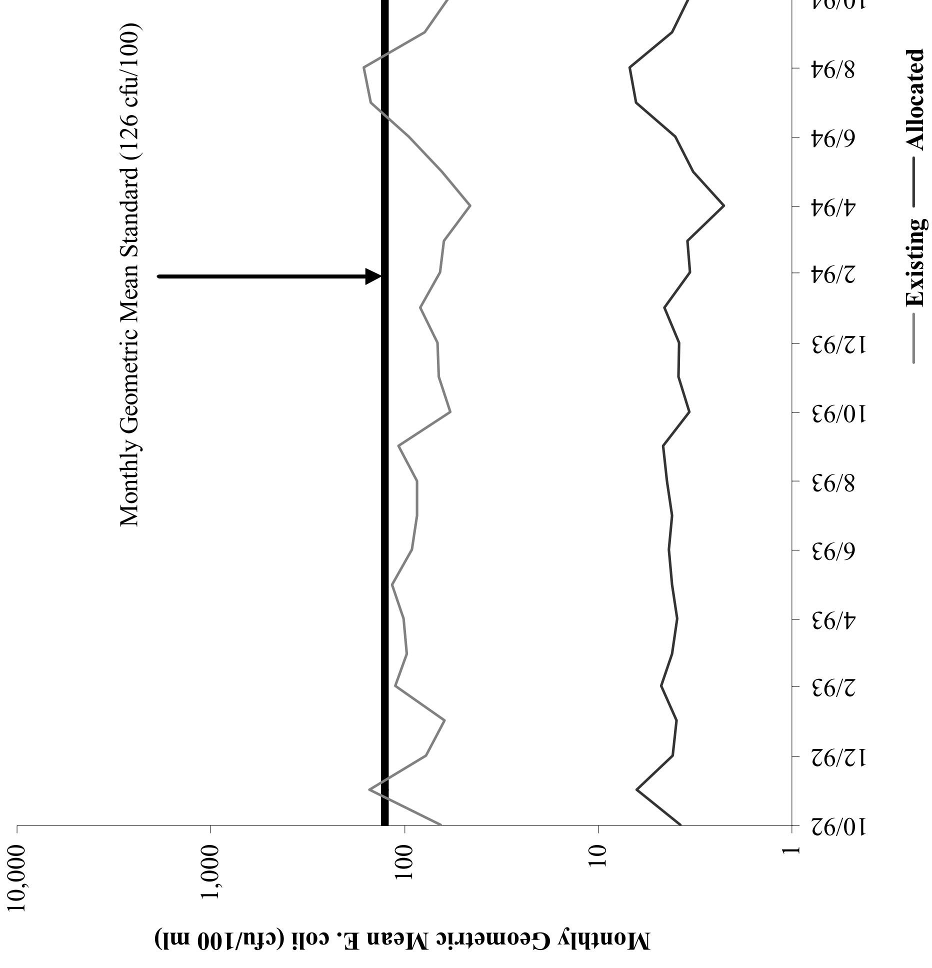

Figure 5.13 Existing and allocation scenarios of *E. coli* concentrations in model segment 2 subwatershed 16, North River impairment.

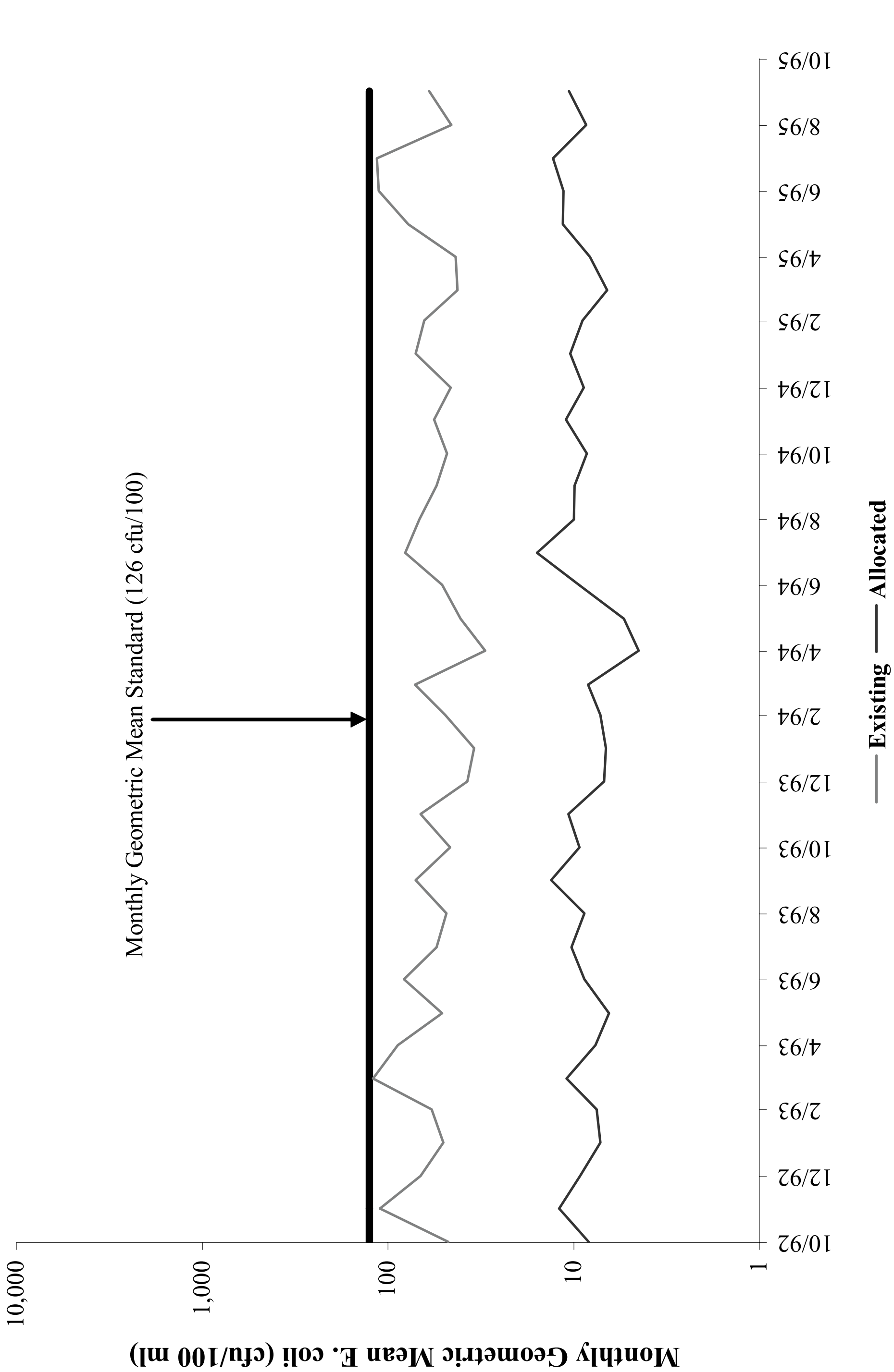

Figure 5.14 Existing and allocation scenarios of *E. coli* concentrations in segment 4 subwatershed 17, Troublesome Branch impairment.

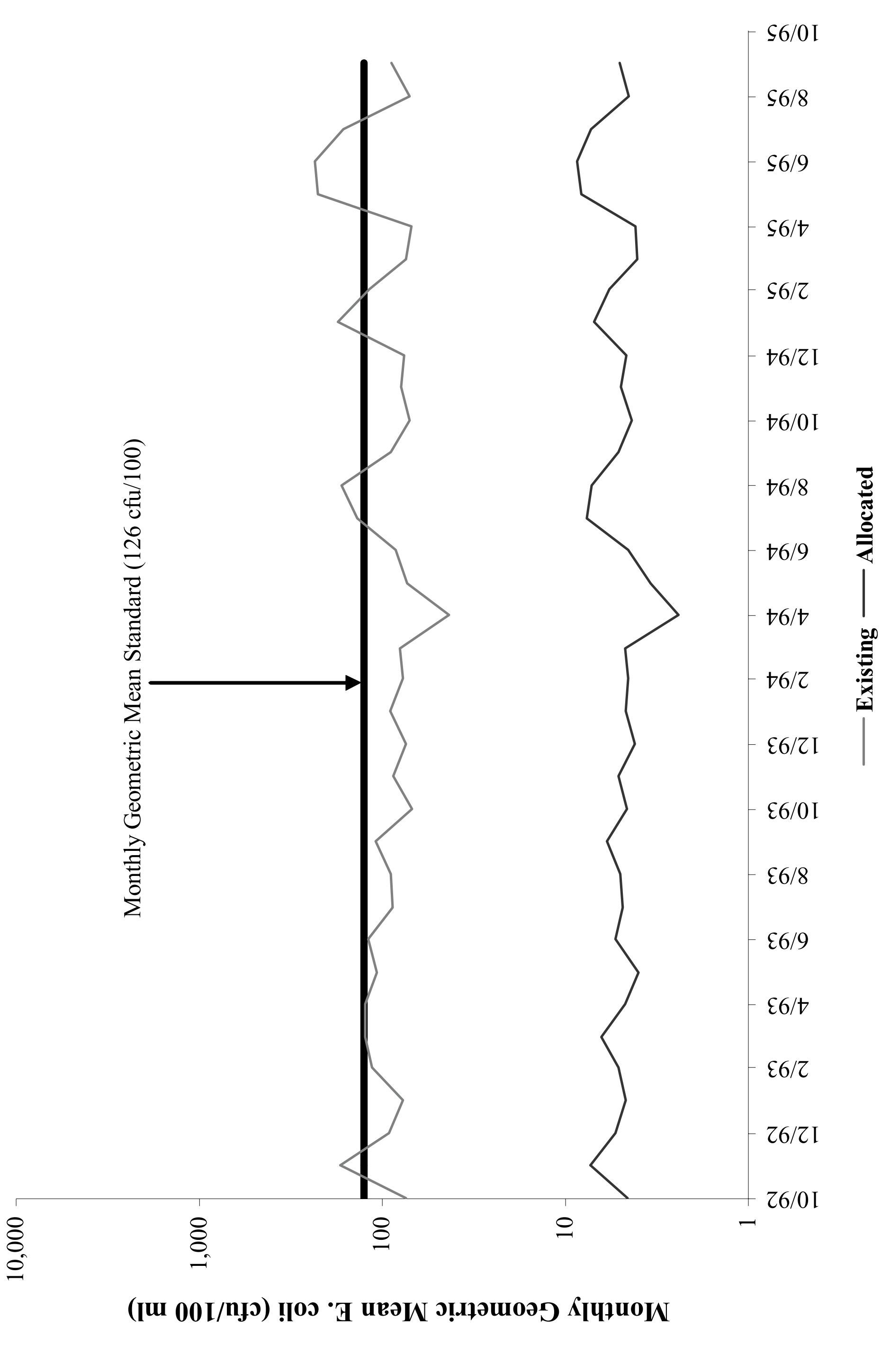

Figure 5.15 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 10, Lower Slate River impairment.

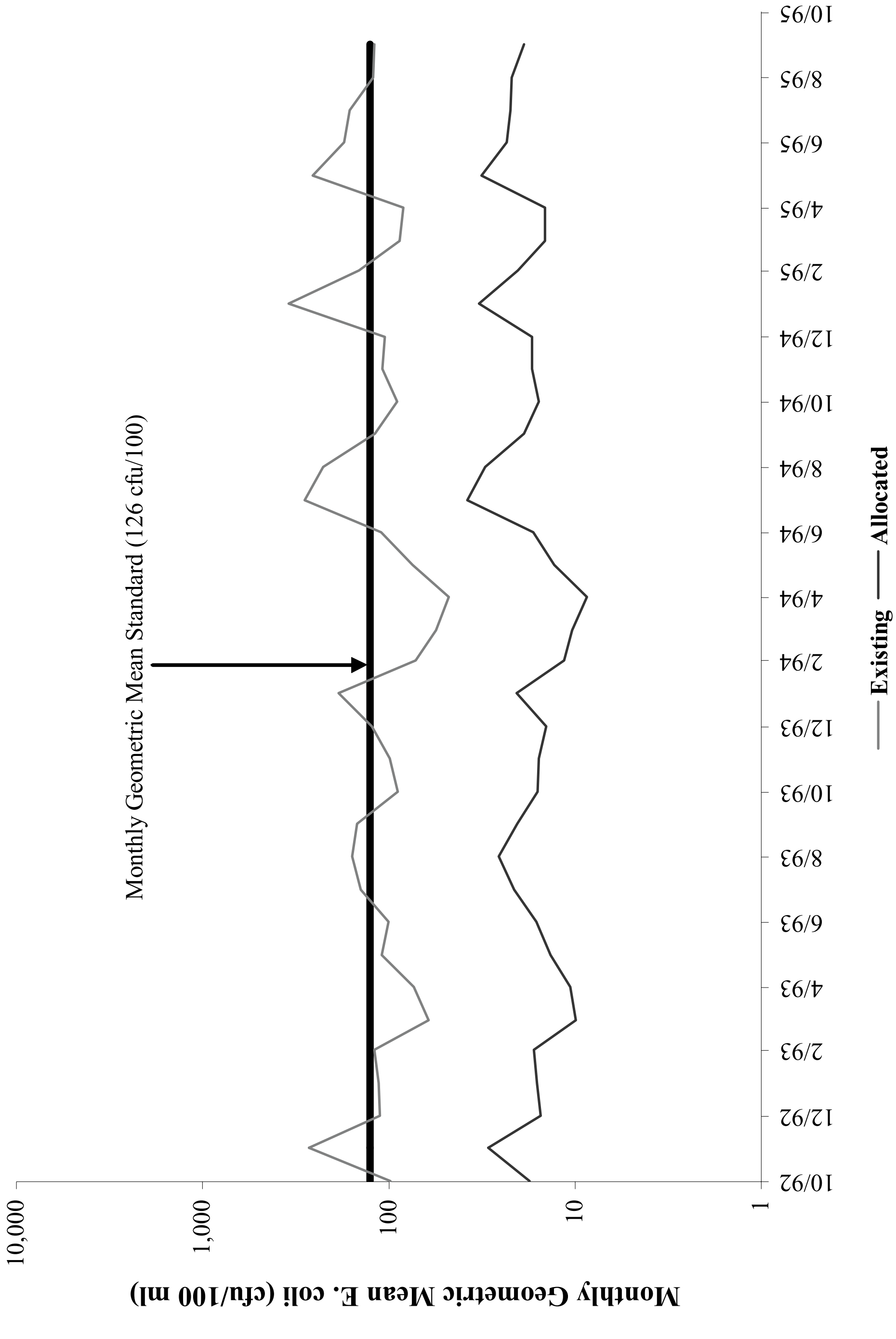

Figure 5.16 Existing and allocation scenarios of *E. coli* concentrations in model segment 6 subwatershed 34, Rock Island Creek impairment.

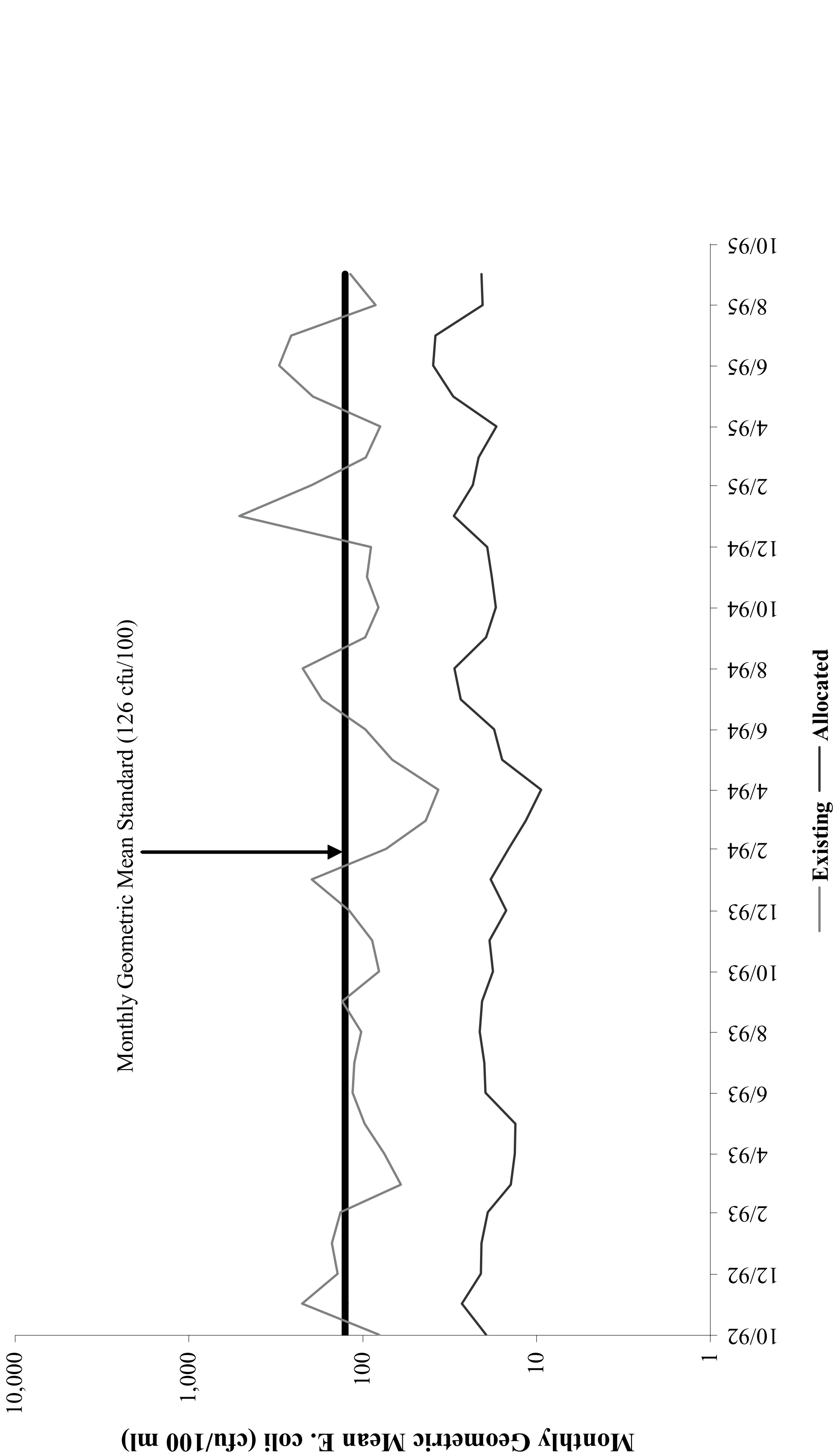

Figure 5.17 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 37, Ballinger Creek impairment.

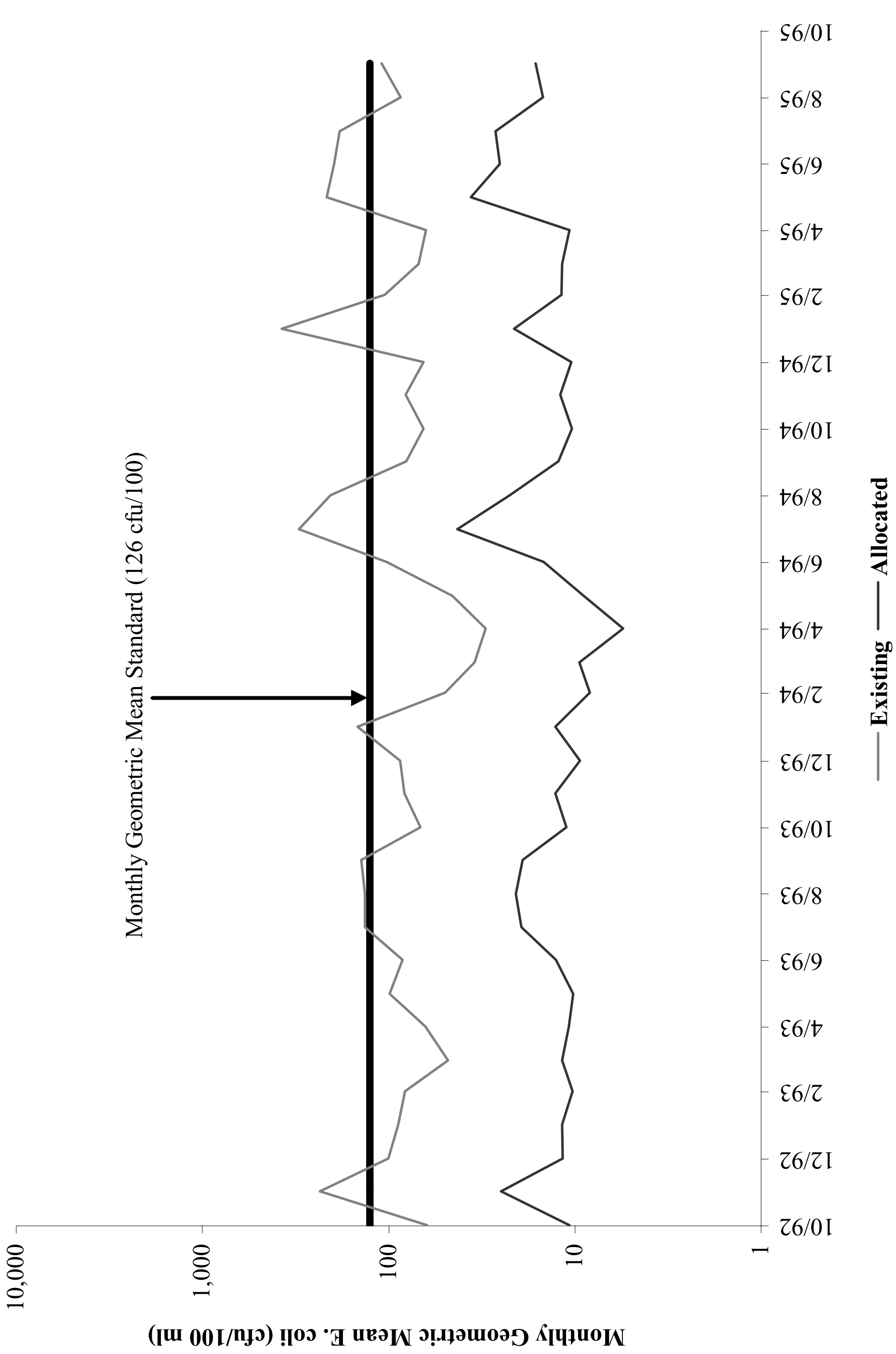

Figure 5.18 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 39, Totier Creek impairment.

Tables 5.10 through 5.18 contain the existing and allocated loads for all the impairments in the James River Tributaries in Albemarle and Buckingham Counties Study Area, reported as total annual fecal coliform colony forming units (cfu) per year from both direct and land-based sources. The percent reduction needed to meet zero percent violations of water quality standards is given in the final column of these tables. Table 5.19 is known as the TMDL table, which gives the number of cfu of *E. coli* that can reach the stream in a given year, and still meet existing water quality standards. These figures are broken up into Waste Load Allocation (WLA), or the portion of fecal coliform that may come from permitted discharge sources and Load Allocation (LA), or the portion of fecal coliform that may come from the non-permitted non-point sources existing in the watershed. Table 5.20 is known as the Daily TMDL table where the daily TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Table 5.10 Land-based and Direct nonpoint source fecal coliform load reductions in the Frisby Branch impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	1.66E+12	1.66E+12	0.0
Forest	3.66E+13	3.66E+13	0.0
Livestock Access	1.97E+12	1.38E+10	99.3
Residential	4.23E+12	2.96E+10	99.3
Pasture	3.72E+14	2.60E+12	99.3
RowCrop	4.21E+11	2.95E+09	99.3
Wetlands	2.14E+12	2.14E+12	0.0
Direct			
Human	4.12E+12	0.00E+00	100.0
Livestock	7.34E+11	0.00E+00	100.0
Wildlife	8.58E+11	8.58E+11	0.0

Table 5.11 Land-based and direct source fecal coliform load reductions in the Austin Creek impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	2.34E+12	2.34E+11	90.0
Forest	4.92E+13	4.92E+12	90.0
Livestock Access	4.90E+11	4.90E+09	99.0
Residential	2.25E+12	2.25E+10	99.0
Pasture	1.72E+14	1.72E+12	99.0
Cropland	8.88E+10	8.88E+08	99.0
Wetlands	7.91E+12	7.91E+11	90.0
Direct			
Human	2.65E+12	0.00E+00	100.0
Livestock	2.09E+11	0.00E+00	100.0
Wildlife	1.14E+12	5.70E+11	50.0

Table 5.12 Land-based and direct source fecal coliform load reductions in the Upper Slate River impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	2.56E+13	2.56E+11	99.0
Commercial	4.00E+11	4.00E+09	99.0
Forest	7.96E+14	7.96E+12	99.0
Livestock Access	5.85E+13	2.93E+11	99.5
Residential	8.10E+13	8.10E+11	99.0
Pasture	8.79E+15	4.40E+13	99.5
RowCrop	2.88E+15	1.44E+13	99.5
Wetlands	7.63E+13	7.63E+11	99.0
Direct			
Human/Pet	7.50E+13	0.00E+00	100.0
Livestock	2.24E+13	0.00E+00	100.0
Wildlife	2.10E+13	2.10E+11	99.0

Table 5.13 Land-based and direct source fecal coliform load reductions in the Troublesome Creek impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	1.79E+12	1.79E+12	0.0
Commercial	2.14E+11	4.28E+10	80.0
Forest	5.28E+13	5.28E+13	0.0
Livestock Access	4.49E+12	4.49E+10	99.0
Residential	1.63E+13	3.26E+12	80.0
Pasture	7.45E+14	7.45E+12	99.0
RowCrop	1.23E+15	1.23E+13	99.0
Wetlands	2.51E+12	2.51E+12	0.0
Direct			
Human/Pet	1.45E+13	0.00E+00	100.0
Livestock	1.73E+12	0.00E+00	100.0
Wildlife	1.73E+12	1.73E+12	0.0

Table 5.14 Land-based and direct source fecal coliform load reductions in the North River impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	9.04E+12	2.71E+11	97.0
Forest	2.48E+14	7.44E+12	97.0
Livestock Access	2.03E+13	1.02E+11	99.5
Residential	1.64E+13	8.20E+10	99.5
Pasture	3.84E+15	1.92E+13	99.5
RowCrop	1.74E+12	8.70E+09	99.5
Wetlands	3.16E+13	9.48E+11	97.0
Direct			
Human	1.69E+13	0.00E+00	100.0
Livestock	7.78E+12	0.00E+00	100.0
Wildlife	6.57E+12	1.97E+11	97.0

Table 5.15 Land-based and direct source fecal coliform load reductions in the Lower Slate River impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	6.34E+13	2.54E+13	60.0
Commercial	9.43E+11	9.43E+09	99.0
Forest	1.76E+15	7.04E+14	60.0
Livestock Access	1.44E+14	1.44E+12	99.0
Residential	1.88E+14	1.88E+12	99.0
Pasture	1.41E+16	1.41E+14	99.0
RowCrop	3.71E+15	3.71E+13	99.0
Wetlands	1.26E+14	5.04E+13	60.0
Direct			
Human	2.08E+14	0.00E+00	100.0
Livestock	5.34E+13	0.00E+00	100.0
Wildlife	4.56E+13	1.82E+13	60.0

Table 5.16 Land-based and direct source fecal coliform load reductions in the Rock Island Creek impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	5.00E+12	8.00E+11	84.0
Commercial	8.67E+08	8.67E+06	99.0
Forest	1.53E+14	2.45E+13	84.0
Livestock Access	6.75E+12	6.75E+10	99.0
Residential	1.90E+13	1.90E+11	99.0
Pasture	2.29E+14	2.29E+12	99.0
RowCrop	7.40E+11	7.40E+09	99.0
Wetlands	1.03E+13	1.65E+12	84.0
Direct			
Human	1.63E+13	0.00E+00	100.0
Livestock	2.61E+12	0.00E+00	100.0
Wildlife	3.56E+12	5.70E+11	84.0

Table 5.17 Land-based and direct source fecal coliform load reductions in the Ballinger Creek impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	7.59E+11	3.72E+11	51.0
Commercial	3.05E+09	3.05E+07	99.0
Forest	1.08E+14	5.29E+13	51.0
Livestock Access	1.46E+13	1.46E+11	99.0
Residential	2.06E+13	2.06E+11	99.0
Pasture	5.22E+14	5.22E+12	99.0
RowCrop	2.82E+12	2.82E+10	99.0
Wetlands	3.53E+12	1.73E+12	51.0
Direct			
Human	1.37E+13	0.00E+00	100.0
Livestock	4.04E+12	0.00E+00	100.0
Wildlife	3.22E+12	1.58E+12	51.0

Table 5.18 Land-based and direct source fecal coliform load reductions in the Totier Creek impairment for final allocation.

Source	Total Annual Loading under Existing Conditions (cfu/yr)	Total Annual Loading under TMDL conditions (cfu/yr)	Percent Reduction
Land Based			
Barren	3.41E+12	3.38E+12	1.0
Commercial	3.67E+10	3.67E+08	99.0
Forest	1.59E+14	1.57E+14	1.0
Livestock Access	1.81E+13	1.81E+11	99.0
Residential	3.45E+13	3.45E+11	99.0
Pasture	9.43E+14	9.43E+12	99.0
RowCrop	5.83E+12	5.83E+10	99.0
Wetlands	1.27E+13	1.26E+13	1.0
Direct			
Human/Pet	1.92E+13	0.00E+00	100.0
Livestock	3.77E+12	0.00E+00	100.0
Wildlife	6.19E+12	6.13E+12	1.0

Table 5.19 Average annual *E. coli* (cfu/year) modeled after TMDL allocation at the outlets of the James River Tributaries in Albemarle and Buckingham Counties Study Area impairments.

Impairment	TMDL Standard	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Frisby Branch	*E. coli*	2.15E+10	2.15E+12	*Implicit*	2.17E+12
Future Growth		*2.15E+10*			
Austin Creek	*E. coli*	1.62E+10	1.63E+12		1.65E+12
Future Growth		*1.62E+10*			
Slate River (upper)	*E. coli*	4.22E+10	1.41E+13		1.41E+13
VA0063291		*8.70E+09*			
VA0087563		*5.57E+09*			
Future Growth		*2.79E+10*			
North River	*E. coli*	5.52E+10	5.57E+12		5.63E+12
Future Growth		*5.52E+10*			
Troublesome Creek	*E. coli*	5.23E+10	*2.69E+12*		2.74E+12
VA0063291		*8.70E+09*			
Future Growth		*4.36E+10*			
Slate River (lower)	*E. coli*	3.19E+12	5.38E+13		5.70E+13
VA0063291		*8.70E+09*			
VA0066460		*5.22E+11*			
VA0087563		*5.57E+09*			
VAG404041		*6.96E+08*			
VAG404116		*1.74E+09*			
VAG404166		*1.74E+09*			
VAG407204		*8.70E+08*			
VAG407237		*1.57E+09*			
VAG407251		*7.83E+08*			
Future Growth		*2.65E+12*			
Rock Island Creek	*E. coli*	3.38E+10	3.38E+12		3.41E+12
Future Growth		*3.38E+10*			
Ballinger Creek	*E. coli*	5.75E+10	5.76E+12		5.82E+12
Future Growth		*5.75E+10*			
Totier Creek	*E. coli*	1.62E+11	1.75E+13		1.77E+13
Future Growth		*1.62E+11*			

Table 5.20 Daily maximum *E. coli* loads (cfu/day) for the James River Tributaries in Albemarle and Buckingham Counties Study Area impairments.

Impairment	TMDL Standard	WLA[1] (cfu/day)	LA (cfu/day)	MOS	TMDL[2] (cfu/day)
Frisby Branch	E. coli	5.89E+07	2.15E+11	Implicit	2.15E+11
Austin Creek	E. coli	4.44E+07	3.23E+11		3.23E+11
Slate River (upper)	E. coli	1.16E+08	5.88E+12		5.88E+12
North River	E. coli	*1.51E+08*	1.71E+12		1.71E+12
Troublesome Creek	E. coli	1.43E+08	3.08E+11		3.08E+11
Slate River (lower)	E. coli	*8.75E+09*	1.17E+13		1.17E+13
Rock Island Creek	E. coli	9.26E+07	1.12E+12		1.12E+12
Ballinger Creek	E. coli	1.58E+08	7.73E+11		7.73E+11
Totier Creek	E. coli	4.44E+08	1.90E+12		1.90E+12

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals

6. TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

6.1 Continuing Planning Process and Water Quality Management Planning

As part of the Continuing Planning Process, DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on DEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

6.2 Staged Implementation

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following implementation through follow-up stream monitoring;

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3. It provides a mechanism for developing public support through periodic updates on implementation levels and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

6.3 Implementation of Waste Load Allocations

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program. Requirements of the permit process should not be duplicated in the TMDL process, and permitted sources are not usually addressed through the development of any TMDL implementation plans.

6.4 Stormwater

DEQ and DCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. DEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while DCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented.

6.5 TMDL Modifications for New or Expanding Dischargers

Permits issued for facilities with wasteload allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, DEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on DEQ's web site at http://www.deq.virginia.gov/waterguidance/

6.6 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

6.6.1 Implementation Plan development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19.7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments". EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

In order to qualify for other funding sources, such as EPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control. One of the most efficient bacterial BMPs is excluding animals from the stream.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effectivce and reasonable BMPs, a Use Attainability Analysis may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and

§306 of Clean Water Act, and cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in section 7.6, Attainability of Designated Uses.

The goal of the Stage 1 scenarios is to reduce the bacteria loadings from controllable sources, excluding wildlife. The Stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios.

The goal of the Stage 1 scenario is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10.5 percent. The Stage 1 scenario was generated with the same model setup as was used for the TMDL allocation scenarios (Tables 6.1 through 6.9). Tables 6.10 throught 6.18 detail the load reductions required for meeting the Stage 1 Implementation for the James River Tributaries in Albemarle and Buckingham Counties.

Table 6.1 Bacteria reduction scenarios for Frisby Branch.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	54	100	54	2.78	10.24
1(b)[1]	0	0	53.5	53.5	100	53.5	5.56	10.42
1(c)[1]	0	0	0	55	100	0	5.56	10.33
2[2]	0	0	100	99.3	100	99.3	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.2 Bacteria reduction scenarios for Austin Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	72	100	72	5.56	10.42
1(b)[1]	0	0	72.2	72.2	100	72.2	5.56	10.42
1(c)[1]	0	0	0	75	100	0	5.56	10.24
2[2]	50	90	100	99	100	99	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.3 Bacteria reduction scenarios for Upper Slate River.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	55	100	55	0.00	10.33
1(b)[1]	0	0	57	57	100	57	0.00	10.42
1(c)[1]	0	0	0	60	100	0	0.00	10.42
2[2]	99	99	100	99.5	100	99	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.4 Bacteria reduction scenarios for North River.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	76	100	76	0.00	10.42
1(b)[1]	0	0	76	76	100	76	0.00	10.42
1(c)[1]	0	0	0	83	100	0	0.00	10.42
2[2]	97	97	100	99.5	100	99.5	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.5 Bacteria reduction scenarios for Troublesome Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	7.5	100	7.5	0.00	10.42
1(b)[1]	0	0	8	8	100	8	0.00	10.33
1(c)[1]	0	0	0	15	100	0	0.00	10.33
2[2]	0	0	100	99	100	80	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.6 Bacteria reduction scenarios for Lower Slate River.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	39.5	100	39.5	0.00	10.33
1(b)[1]	0	0	40	40	100	40	0.00	10.33
1(c)[1]	0	0	0	45	100	0	0.00	10.24
2[2]	60	60	100	99	100	99	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.7 Bacteria reduction scenarios for Rock Island Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	68.5	100	68.5	0.00	10.33
1(b)[1]	0	0	69	69	100	69	0.00	10.24
1(c)[1]	0	0	0	94	100	0	0	10.42
2[2]	84	84	100	99	100	99	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.8 Bacteria reduction scenarios for Ballinger Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	52	100	52	2.78	10.42
1(b)[1]	0	0	53.2	53.2	100	53.2	2.78	10.33
1(c)[1]	0	0	0	75	100	0	0.00	7.4
2[2]	51	51	100	99	100	99	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.9 Bacteria reduction scenarios for Totier Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)[1]	0	0	99	70	100	70	8.33	10.42
1(b)[1]	0	0	70.5	70.5	100	70.5	8.33	10.33
1(c)[1]	0	0	0	80	100	0	19.44	10.42
2[2]	1	1	100	99	100	99	0.00	0.00

[1]Stage 1 implementation scenario.
[2]Final TMDL allocation.

Table 6.10 Fecal coliform land-based loads deposited on all land uses and direct loads in the Frisby Branch watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	1.66E+12	1.66E+12	0
Forest	3.66E+13	3.66E+13	0
Livestock Access	1.97E+12	9.16E+11	53.5
Residential	4.23E+12	1.97E+12	53.5
Pasture	3.72E+14	1.73E+14	53.5
RowCrop	4.21E+11	1.96E+11	53.5
Wetlands	2.14E+12	2.14E+12	0
Direct			
Human	4.12E+12	0.00E+00	100
Wildlife	7.34E+11	7.34E+11	0
Livestock	8.58E+11	3.99E+11	53.5

*Scenario 1(b) from Table 6.1.

Table 6.11 Fecal coliform land-based loads deposited on all land uses and direct loads in the Austin Creek watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	2.34E+12	2.34E+12	0
Forest	4.92E+13	4.92E+13	0
Livestock Access	4.90E+11	1.36E+11	72.2
Residential	2.25E+12	6.26E+11	72.2
Pasture	1.72E+14	4.78E+13	72.2
RowCrop	8.88E+10	2.47E+10	72.2
Wetlands	7.91E+12	7.91E+12	0
Direct			
Human	2.65E+12	0.00E+00	100
Wildlife	2.09E+11	0.00E+00	100
Livestock	1.14E+12	3.17E+11	72.2

*Scenario 1(b) from Table 6.2.

Table 6.12 Fecal coliform land-based loads deposited on all land uses and direct loads in the Upper Slate River watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	2.56E+13	2.56E+11	0
Commercial	4.00E+11	1.72E+11	57
Forest	7.96E+14	7.96E+14	0
Livestock Access	5.85E+13	2.52E+13	57
Residential	8.10E+13	3.48E+13	57
Pasture	8.79E+15	3.78E+15	57
RowCrop	2.88E+15	1.24E+15	57
Wetlands	7.63E+13	7.63E+11	0
Direct			
Human	7.50E+13	0.00E+00	100
Wildlife	2.24E+13	0.00E+00	100
Livestock	2.10E+13	9.03E+12	57

*Scenario 1(b) from Table 6.3.

Table 6.13 Fecal coliform land-based loads deposited on all land uses and direct loads in the Troublesome Creek watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	1.79E+12	1.79E+12	0
Commercial	2.14E+11	1.97E+11	8
Forest	5.28E+13	5.28E+13	0
Livestock Access	4.49E+12	4.13E+12	8
Residential	1.63E+13	1.50E+13	8
Pasture	7.45E+14	6.85E+14	8
RowCrop	1.23E+15	1.13E+15	8
Wetlands	2.51E+12	2.51E+12	0
Direct			
Human	1.45E+13	0.00E+00	100
Wildlife	1.73E+12	0.00E+00	100
Livestock	1.73E+12	1.59E+12	8

*Scenario 1(b) from Table 6.5.

Table 6.14 Fecal coliform land-based loads deposited on all land uses and direct loads in the North River watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	9.04E+12	9.04E+12	0
Forest	2.48E+14	2.48E+14	0
Livestock Access	2.03E+13	4.87E+12	76
Residential	1.64E+13	3.94E+12	76
Pasture	3.84E+15	9.22E+14	76
RowCrop	1.74E+12	4.18E+11	76
Wetlands	3.16E+13	3.16E+13	0
Direct			
Human	1.69E+13	0.00E+00	100
Wildlife	7.78E+12	0.00E+00	100
Livestock	6.57E+12	1.58E+12	76

*Scenario 1(b) from Table 6.4.

Table 6.15 Fecal coliform land-based loads deposited on all land uses and direct loads in the Lower Slate River watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	6.34E+13	6.34E+13	0
Commercial	9.43E+11	5.66E+11	40
Forest	1.76E+15	1.76E+15	0
Livestock Access	1.44E+14	8.64E+13	40
Residential	1.88E+14	1.13E+14	40
Pasture	1.41E+16	8.46E+15	40
RowCrop	3.71E+15	2.23E+15	40
Wetlands	1.26E+14	1.26E+14	0
Direct			
Human	2.08E+14	0.00E+00	100
Livestock	5.34E+13	0.00E+00	100
Wildlife	4.56E+13	2.74E+13	40

*Scenario 1(b) from Table 6.6.

Table 6.16 Fecal coliform land-based loads deposited on all land uses and direct loads in the Rock Island Creek watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	5.00E+12	5.00E+12	0
Commercial	8.67E+08	2.69E+08	69
Forest	1.53E+14	1.53E+14	0
Livestock Access	6.75E+12	2.09E+12	69
Residential	1.90E+13	5.89E+12	69
Pasture	2.29E+14	7.10E+13	69
RowCrop	7.40E+11	2.29E+11	69
Wetlands	1.03E+13	1.03E+13	0
Direct			
Human	1.63E+13	0.00E+00	100
Livestock	2.61E+12	0.00E+00	100
Wildlife	3.56E+12	1.10E+12	69

*Scenario 1(b) from Table 6.7.

Table 6.17 Fecal coliform land-based loads deposited on all land uses and direct loads in the Ballinger Creek watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	7.59E+11	7.59E+11	0
Commercial	3.05E+09	1.43E+09	53.2
Forest	1.08E+14	1.08E+14	0
Livestock Access	1.46E+13	6.83E+12	53.2
Residential	2.06E+13	9.64E+12	53.2
Pasture	5.22E+14	2.44E+14	53.2
RowCrop	2.82E+12	1.32E+12	53.2
Wetlands	3.53E+12	3.53E+12	0
Direct			
Human	1.37E+13	0.00E+00	100
Livestock	4.04E+12	0.00E+00	100
Wildlife	3.22E+12	1.51E+12	53.2

*Scenario 1(b) from Table 6.8.

Table 6.18 Fecal coliform land-based loads deposited on all land uses and direct loads in the Totier Creek watershed for existing conditions and for the Stage 1 implementation management scenario.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Stage 1 Run (cfu/yr)	Percent Reduction*
Land Based			
Barren	3.41E+12	3.41E+12	0
Commercial	3.67E+10	1.08E+10	70.5
Forest	1.59E+14	1.59E+14	0
Livestock Access	1.81E+13	5.34E+12	70.5
Residential	3.45E+13	1.02E+13	70.5
Pasture	9.43E+14	2.78E+14	70.5
RowCrop	5.83E+12	1.72E+12	70.5
Wetlands	1.27E+13	1.27E+13	0
Direct			
Human	1.92E+13	0.00E+00	100
Livestock	3.77E+12	0.00E+00	100
Wildlife	6.19E+12	1.83E+12	70.5

*Scenario 1(b) from Table 6.9.

6.7 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. The BMPs required for the implementation of the bacteria allocations in these watersheds contributes directly to the sediment reduction goals set as part of the Chesapeake Bay restoration effort. Several BMPs known to be effective in controlling bacteria have also been identified for implementation as part of the Commonwealth of Virginia James River Basin Tributary Strategy. For example, stream protection with fencing and rotational grazing are among the BMPs discussed as part of the strategy. Up-to-date information on the tributary strategy implementation process can be found at the Virginia tributary strategy web site under the James River Tributary Strategy link: http://www.snr.state.va.us/Initiatives/WaterQuality/.

6.8 Implementation Funding Sources

The implementation on pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding stream for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/bay/wqif.html and at http://www.dcr.virginia.gov/sw/wqia.htm .

6.9 Follow-Up Monitoring

VADEQ will continue to monitor bacteria in the impaired streams at the TMDL listing stations (2-TOT002.61, 2-BLR003.00, 2-RKI003.40, 2-FRY000.35, 2-FRY003.00, 2-AUS001.12, 2-NTH001.65, 2-NTH003.88, 2-TBM000.80, 2-SLT024.72, 2-SLT030.19 and 2-SLT003.88) according to its ambient monitoring program. When an

Implementation Plan is developed for these streams and implementation of that plan begins, DEQ will increase the frequency of monitoring at these sites to assess water quality progress as BMPs are implemented.

6.10 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;

2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or

6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment during this process. Additional information can be obtained at

http://www.deq.virginia.gov/wqs/pdf/WQS05A_1.pdf

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation would be for the reductions of all controllable sources to the maximum extent practicable using the implementation approaches described above. DEQ will continue to monitor biological health and water quality in the stream during and subsequent to the implementation of these measures to determine if water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E. provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board.

The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed."

7. PUBLIC PARTICIPATION

The development of the James River Tributaries in Albemarle and Buckingham Counties TMDLs greatly benefited from public involvement. Table 7.1 details the public participation throughout the project. The Local Steering Committee (LSC) meeting took place on June 21, 2006 at the Scottsville Town Council Chambers in Scottsville, Virginia with 18 persons in attendance. The meeting brought together representatives from VADCR, VADEQ, VDH, the Rivanna Service Authority, the Thomas Jefferson and Peter Francisco Soil and Water Conservation Districts and MapTech, Inc. All agency representatives and county and locality staff were invited to the TAC meeting through a mailed letter or e-mail.

The first public meeting was held at the Buckingham County Administration Building in Buckingham, Virginia on August 10, 2006; 20 people attended, including 13 local stakeholders, one consultant, two Albemarle County representatives and four agency representatives. The meeting was publicized by placing notices in the Virginia Register, the Farmville newspaper, mailing notices to, all agencies and placing signs on the road right-of-way in the impaired watersheds.

The second Local Steering Committee meeting took place on April 30, 2007 at the Peter Francisco Soil and Water District Office near Buckingham, Virginia. All agency representatives and county and locality staff were invited to the LSC meeting through a mailed letter or e-mail. The final public meeting was held at the Scottsville Town Council Chambers in Scottsville, Virginia on May 10, 2007. The meeting was publicized by placing notices in the Virginia Register, the Farmville newspaper, mailing notices to, all agencies and placing signs on the road right-of-way in the impaired watersheds. Sixteen people attended including four agency representatives, one consultant, one Rivanna Water and Sewer Authority representative, one Albemarle County representative and nine stakeholders.

Table 7.1 Public participation during TMDL development for the James River Tributaries in Albemarle and Buckingham Counties watersheds.

Date	Location	Attendance[1]	Type	Format
6/21/2006	Scottsville Town Council Chambers Scottsville, VA	18	LSR meeting	Publicized to government agencies
8/10/2006	Buckingham County Administration Building Buckingham, VA	20	1st public	Open to public at large
4/30/2007	Peter Francisco Soil and Water District Office Buckingham, VA	10	LSR meeting	Publicized to government agencies
5/10/2007	Scottsville Town Council Chambers Scottsville, VA	16	2nd public	Open to public at large

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

Public participation during the implementation plan development process will include the formation of a stakeholders' committee as well as open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders' committee will have the express purpose of formulating the TMDL Implementation Plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from DMME, VADEQ, VADCR, and local governments. This committee will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

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GLOSSARY

Note: All entries in italics are taken from USEPA (1998).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A waste load allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity. *The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota. **(2)**

Biochemical Oxygen Demand (BOD). Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biological Integrity. A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Cause. 1. That which produces an effect (a general definition).
2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition).[2]

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Concentration-response model. A quantitative (usually statistical) model of the relationship between the concentration of a chemical to which a population or community of organisms is exposed and the frequency or magnitude of a biological response. (2)

Conductivity. An indirect measure of the presence of dissolved substances within water.

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition*. Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration.***

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES)*. A permit issued by the EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion*. The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Dissolved Oxygen (DO). The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Erosion. The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Fate of pollutants. *Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

General Standard. A narrative standard that ensures the general health of state waters. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (4)

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph*. A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle*. The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology*. The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Impairment. A detrimental effect on the biological integrity of a water body that prevents attainment of the designated use.

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism*. An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause.

Indirect effects. Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor.

Infiltration capacity*. The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate*. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by the EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mass balance. *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

Mass loading. *The quantity of a pollutant transported to a waterbody.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

Metric ton (Mg or t). A unit of mass equivalent to 1,000 kilograms. An annual load of a pollutant is typically reported in metric tons per year (t/yr).

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

Model. Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nitrogen. An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

Peak runoff*. The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (*e.g.*, pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by the EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased/staged approach. *Under the phased approach to TMDL development, load allocations and waste load allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Phosphorus. An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works*. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period*. The time allowed for the public to express its views and concerns regarding action by the EPA or states (e.g., a* Federal Register *notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25th, 50th, and 75th percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50th quartile is also known as the median. The 25th and 75th quartiles are referred to as the lower and upper quartiles, respectively.

Rapid Bioassessment Protocol II (RBP II). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP II scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach. Segment of a stream or river.

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reference Conditions. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Re-mining. Extracting resources from land previously mined. This method is often used to reclaim abandoned mine areas.

Reserve capacity*. Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration*. Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone*. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient*. A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles. (Gilbert, 1987)

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquate systems as a result of erosion.

Septic system*. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Simulation*. The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Source. An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor.

Spatial segmentation*. A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Staged Implementation. A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 mL geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Storm runoff*. Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream Reach. A straight portion of a stream.

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Stressor. Any physical, chemical, or biological entity that can induce an adverse response. [2]

Surface area*. The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water*. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Suspended Solids. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

Technology-based standards*. Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Ton (T). A unit of measure of mass equivalent to 2,200 English lbs.

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Dissolved Solids (TDS). A measure of the concentration of dissolved inorganic chemicals in water.

Total Maximum Daily Load (TMDL). *The sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

TMDL Implementation Plan. A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

TRC. Total Residual Chlorine. A measure of the effectiveness of chlorinating treated waste water effluent.

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Urban Runoff. Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

DMLR. Virginia Department of mine Land Reclamation.

DMME. Virginia Department of Mines, Minerals, and Energy.

VDH. Virginia Department of Health.

Waste load allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

Wastewater treatment*. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality*. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based permit*. A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria*. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by the EPA or states* *for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

APPENDIX A

Trend and Seasonality Tables

Table A. 1 Summary of trend analysis on flow (cfs).

Station	Mean	Median	Max	Min	SD[1]	N[2]	Significant Trend[3]
USGS #02030500	225.27	175.58	2009.43	7.43	191.38	823	No Trend

[1]SD: standard deviation, [2]N: number of sample measurements, [3]A number in the significant trend column represents the Seasonal-Kendall estimated slope.

Table A. 2 Summary of the Mood's Median Test on mean monthly flow at USGS Station 02030500 ($p<0.001$).

Month	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Median Groups			
January	281.40	47.16	991.58			C	D
February	337.20	66.96	969.32				D
March	373.93	80.19	1035.00				D
April	331.67	91.77	894.73				D
May	224.13	67.58	911.74			C	
June	179.01	37.60	2009.43		B		
July	130.25	19.72	497.81	A	B		
August	141.19	14.68	799.97	A	B		
September	143.83	7.43	871.63	A			
October	148.13	11.74	778.13	A	B		
November	179.96	38.80	866.93		B	C	
December	236.67	36.74	998.42			C	D

Table A. 3 Summary of trend analysis on precipitation (in).

Station Name	Station #	Mean	Median	Max	Min	SD[1]	N[2]	Significant Trend[3]
Buckingham	441136	5.73	3.14	309.69	0.00	23.94	524	No Trend
Bremo	440993	10.55	3.32	309.69	0.00	40.32	644	No Trend
Palmyra	446491	5.08	3.04	309.69	0.01	16.59	557	No Trend

[1]SD: standard deviation; [2]N: number of sample measurements; [3]A number in the significant trend column represents the Seasonal-Kendall estimated slope; "--" insufficient data

Table A. 4 Summary of trend analysis on fecal coliform (cfu).

Station	Mean	Median	Max	Min	SD[1]	N[2]	Significant Trend[3]
2-NTH001.65	870	200	9,200	18	1,742	49	No Trend
2-RKI003.40	608	200	16,000	18	2,190	53	No Trend
2-SLT003.68	468	100	5,700	18	1,174	77	No Trend
2-TOT002.61	605	200	8,000	25	1,323	107	-5.556
2-AUS001.12	275	92	1,300	15	396	10	--
2-BAL003.00	443	200	2,500	100	562	23	--
2-FRY000.35	81	140	5,400	45	1,818	9	--
2-FRY003.00	1,103	130	5,400	45	1,842	10	--
2-SLT024.72	2,692	215	16,000	45	5,464	10	--
2-SLT030.19	1,732	395	9,200	78	2,857	10	--
2-TBM000.80	1,744	89	16,000	18	5,014	10	--

[1]SD: standard deviation, [2]N: number of sample measurements, [3]A number in the significant trend column represents the Seasonal-Kendall estimated slope. A negative number indicates a downward trend and a positive number indicates an upward trend, "--" insufficient data

APPENDIX B

Summarized BST Results

Table B.1 Summary of bacterial source tracking results from water samples collected in the Austin Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Wildlife	Human	Livestock	Pet
2AUS001.12	07/20/05	180	84	**12%**	**50%**	0%	**38%**
2AUS001.12	08/23/05	100	46	20%	40%	20%	20%
2AUS001.12	09/20/05	310	104	**25%**	**33%**	**21%**	**21%**
2AUS001.12	10/27/05		46	0%	**47%**	**38%**	15%
2AUS001.12	11/29/05		84	8%	**21%**	**46%**	**25%**
2AUS001.12	12/29/05		44	**18%**	**27%**	9%	**46%**
2AUS001.12	02/02/06		14	75%	0%	25%	0%
2AUS001.12	03/28/06		8	50%	0%	0%	50%
2AUS001.12	4/25/06		66	**59%**	8%	**21%**	**12%**

BOLD type indicates a statistically significant value.

Table B.2 Summary of bacterial source tracking results from water samples collected in the Ballinger Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Wildlife	Human	Livestock	Pet
2BLR003.00	07/12/05	500	378	**54%**	0%	**46%**	0%
2BLR003.00	08/23/05	300	206	0%	0%	**100%**	0%
2BLR003.00	09/13/05	390	221	8%	**33%**	**26%**	**33%**
2BLR003.00	10/19/05		76	**17%**	**63%**	12%	8%
2BLR003.00	11/15/05		151	**42%**	**42%**	4%	**12%**
2BLR003.00	12/13/05		84	**25%**	**12%**	**25%**	**38%**
2BLR003.00	01/24/06		106	**25%**	12%	**17%**	**46%**
2BLR003.00	02/22/06		96	**29%**	0%	**21%**	**50%**
2BLR003.00	03/15/06		156	**50%**	8%	**25%**	17%
2BLR003.00	4/11/06		96	**58%**	4%	38%	0%

BOLD type indicates a statistically significant value.

Table B.3 Summary of bacterial source tracking results from water samples collected in the Frisby Branch impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Wildlife	Human	Livestock	Pet
2FRY000.35	07/20/05	240	84	**12%**	**12%**	**55%**	**21%**

BOLD type indicates a statistically significant value.

Table B.4 Summary of bacterial source tracking results from water samples collected in the North River impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Wildlife	Human	Livestock	Pet
2NTH001.65	07/20/05	90	62	0%	**33%**	**55%**	**12%**
2NTH001.65	08/23/05	50	28	0%	20%	0%	**80%**
2NTH001.65	09/20/05	20	24	0%	**93%**	7%	0%
2NTH001.65	10/27/05		50	**12%**	**55%**	**25%**	8%
2NTH001.65	11/29/05		183	**12%**	**17%**	**17%**	**54%**
2NTH001.65	12/29/05		80	**22%**	**33%**	12%	**33%**
2NTH001.65	02/02/06		108	**58%**	0%	**42%**	0%
2NTH001.65	03/28/06		68	**75%**	0%	8%	**17%**
2NTH001.65	4/25/06		52	12%	**19%**	**38%**	**31%**

BOLD type indicates a statistically significant value.

Table B.5 Summary of bacterial source tracking results from water samples collected in the Rock Island Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Wildlife	Human	Livestock	Pet
2RKI003.40	07/13/05	180	72	**92%**	0%	8%	0%
2RKI003.40	08/23/05	70	40	**47%**	0%	**47%**	6%
2RKI003.40	09/13/05	310	18	**25%**	**42%**	**25%**	8%
2RKI003.40	10/19/05		149	**17%**	**75%**	4%	4%
2RKI003.40	11/15/05		58	**29%**	8%	0%	**63%**
2RKI003.40	12/13/05		56	**72%**	**12%**	12%	4%
2RKI003.40	01/24/06		56	**71%**	**17%**	8%	4%
2RKI003.40	02/22/06		12	0%	0%	0%	100%
2RKI003.40	03/15/06		20	0%	0%	25%	75%
2RKI003.40	4/11/2006		6	100%	0%	0%	0%

BOLD type indicates a statistically significant value.

Table B.6 Summary of bacterial source tracking results from water samples collected in the Slate River impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as:			
				Wildlife	Human	Livestock	Pet
2SLT003.68	07/20/05	80	36	**29%**	**63%**	4%	4%
2SLT003.68	08/23/05	60	30	**65%**	6%	**29%**	0%
2SLT003.68	09/20/05	140	30	6%	**63%**	6%	**25%**
2SLT003.68	10/27/05		60	**67%**	4%	**25%**	4%
2SLT003.68	11/29/05		80	**29%**	**17%**	4%	**50%**
2SLT003.68	12/29/05		86	**29%**	21%	**17%**	**33%**
2SLT003.68	02/02/06		76	**80%**	7%	13%	0%
2SLT003.68	02/23/06		16	0%	42%	29%	29%
2SLT003.68	03/28/06		16	22%	11%	**45%**	22%
2SLT003.68	4/25/2006		30	**50%**	**29%**	**21%**	0%

BOLD type indicates a statistically significant value.

Table B.7 Summary of bacterial source tracking results from water samples collected in the Slate River impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as:			
				Wildlife	Human	Livestock	Pet
2SLT014.52	07/20/05	130	46	0%	0%	**100%**	0%
2SLT014.52	08/23/05	30	62	8%	4%	**29%**	**59%**
2SLT014.52	09/20/05	110	38	**33%**	**29%**	**19%**	**19%**
2SLT014.52	10/27/05		44	**25%**	**51%**	12%	**12%**
2SLT014.52	11/29/05		149	**17%**	**33%**	8%	**42%**
2SLT014.52	12/29/05		96	**25%**	**12%**	4%	**59%**
2SLT014.52	02/02/06		82	**80%**	8%	0%	**12%**
2SLT014.52	02/23/06		32	**27%**	13%	**60%**	0%
2SLT014.52	03/28/06		58	**34%**	**22%**	**22%**	**22%**
2SLT014.52	4/25/2006		48	63%	**12%**	**25%**	0%

Table B.8 Summary of bacterial source tracking results from water samples collected in the Slate River impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as:			
				Wildlife	Human	Livestoc k	Pet
2SLT030.19	07/20/05	250	82	0%	0%	**75%**	**25%**
2SLT030.19	08/23/05	90	40	11%	11%	11%	**67%**
2SLT030.19	09/20/05	220	176	**29%**	**21%**	**38%**	**12%**
2SLT030.19	10/27/05		46	**32%**	**42%**	**21%**	5%
2SLT030.19	11/29/05		210	**12%**	8%	**51%**	**29%**
2SLT030.19	12/29/05		26	**39%**	**22%**	11%	**28%**
2SLT030.19	02/02/06		84	**88%**	**12%**	0%	0%
2SLT030.19	03/28/06		32	**66%**	0%	7%	**27%**
2SLT030.19	4/25/2006		64	**38%**	0%	**33%**	**29%**

BOLD type indicates a statistically significant value.

Table B.9 Summary of bacterial source tracking results from water samples collected in the Slate River impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as:			
				Wildlife	Human	Livestock	Pet
2SLT036.92	07/20/05	110	42	0%	0%	**100%**	0%
2SLT036.92	08/23/05	70	4	0%	0%	0%	100%
2SLT036.92	09/20/05	200	80	8%	**42%**	8%	**42%**
2SLT036.92	10/27/05		134	4%	**54%**	**25%**	**17%**
2SLT036.92	11/29/2005		48	**17%**	**29%**	8%	**46%**
2SLT036.92	12/28/05		90	**29%**	4%	**17%**	**50%**
2SLT036.92	02/02/06		10	83%	0%	17%	0%
2SLT036.92	03/28/06		10	20%	0%	**40%**	40%
2SLT036.92	4/25/2006		20	**20%**	**25%**	**55%**	0%

BOLD type indicates a statistically significant value.

Table B.10 Summary of bacterial source tracking results from water samples collected in the Troublesome Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as:			
				Wildlife	Human	Livestock	Pet
2TBM000.80	07/20/05	240	48	8%	**42%**	**25%**	**25%**
2TBM000.80	08/23/05	1	2	0%	0%	100%	0%
2TBM000.80	09/20/05	120	102	**33%**	**42%**	8%	**17%**
2TBM000.80	10/27/05		16	60%	40%	0%	0%
2TBM000.80	12/21/05		54	8%	**17%**	**50%**	**25%**
2TBM000.80	12/29/05		24	**70%**	15%	0%	15%
2TBM000.80	02/02/06		4	100%	0%	0%	0%
2TBM000.80	02/23/06		2	0%	0%	100%	0%
2TBM000.80	03/28/06		10	34%	33%	33%	0%
2TBM000.80	4/25/06		4	67%	33%	0%	0%

BOLD type indicates a statistically significant value.

Table B.11 Summary of bacterial source tracking results from water samples collected in the Totier Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as:			
				Wildlife	Human	Livestock	Pet
2TOT002.61	7/20/04		340	0%	0%	**71%**	**29%**
2TOT002.61	8/23/04		110	8%	**23%**	15%	**54%**
2TOT002.61	9/20/04		230	0%	0%	**100%**	0%
2TOT002.61	10/12/04		60	67%	33%	0%	0%
2TOT002.61	11/15/04	250	191	**55%**	**12%**	**25%**	8%
2TOT002.61	12/13/04	110	182	**50%**	**25%**	**17%**	8%
2TOT002.61	1/10/05	110	94	**84%**	**12%**	4%	0%
2TOT002.61	2/14/05	190	235	**29%**	8%	**17%**	**46%**
2TOT002.61	3/21/05	80	86	**16%**	0%	**42%**	**42%**
2TOT002.61	4/18/05	170	460	**25%**	4%	**50%**	**21%**
2TOT002.61	5/23/05	140	282	**12%**	4%	**29%**	**55%**
2TOT002.61	6/13/05	160	205	**25%**	**12%**	**51%**	**12%**

BOLD type indicates a statistically significant value.

APPENDIX C

Water Quality Validation Figures

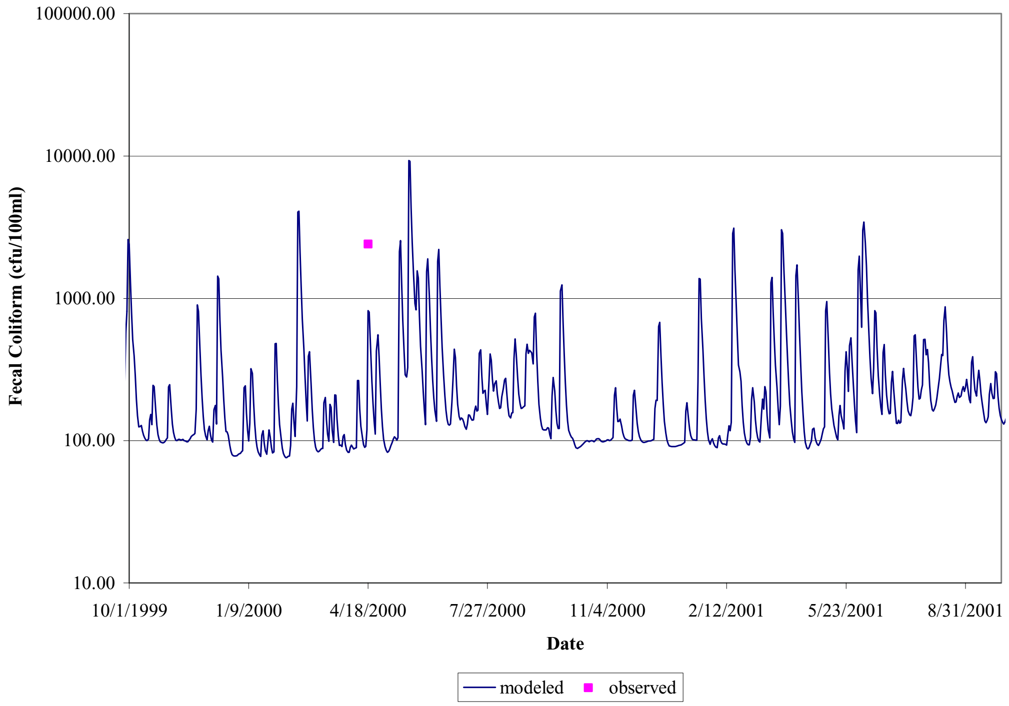

Figure C. 1 Quality validation results for period 10/1/1999 to 9/30/2001 Frisby Branch, subshed 2 VADEQ Station 2-FRY000.35.

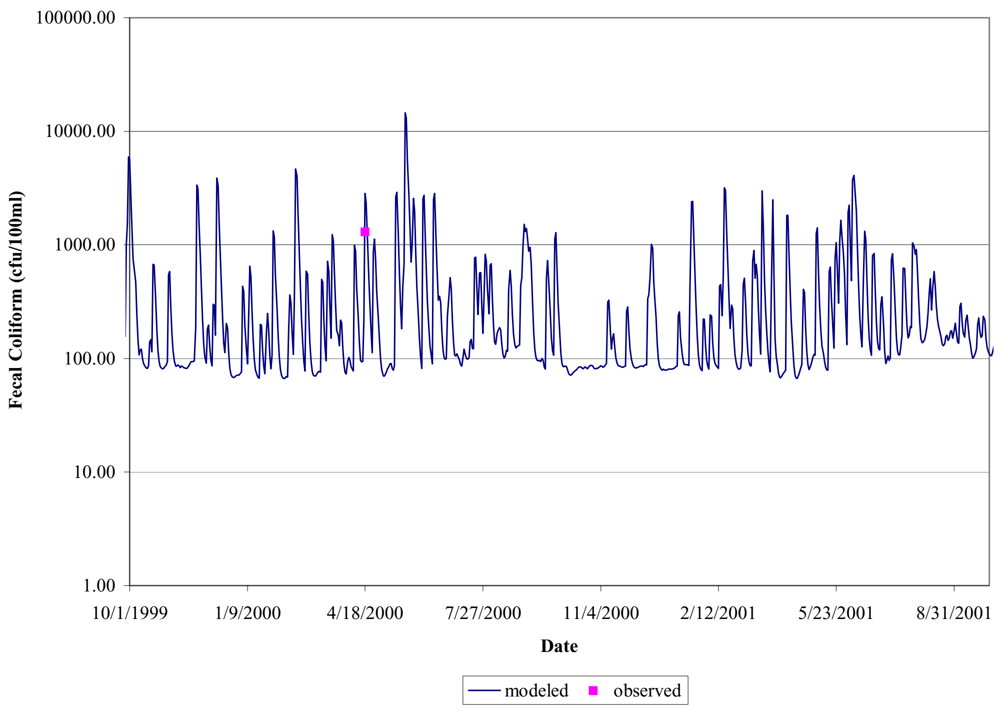

Figure C. 2 Quality validation results for period 10/1/1999 to 9/30/2001 Austin Creek, subshed 13 VADEQ Station 2-AUS001.12.

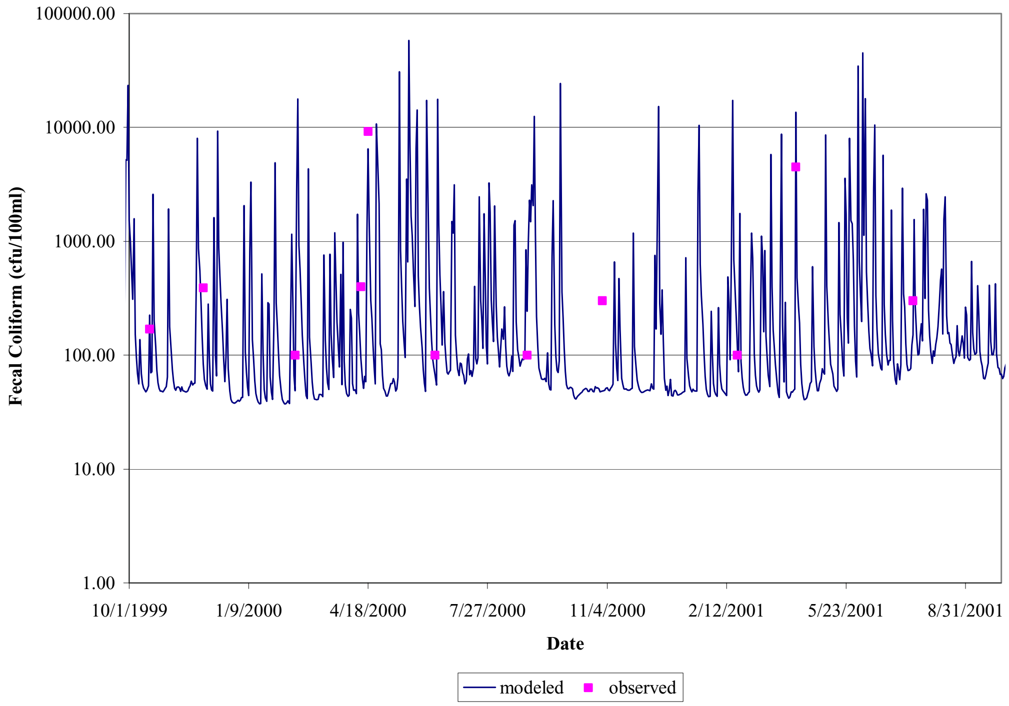

Figure C. 3 Quality validation results for period 10/1/1999 to 9/30/2001 North River, subshed 15 VADEQ Station 2-NTH001.65.

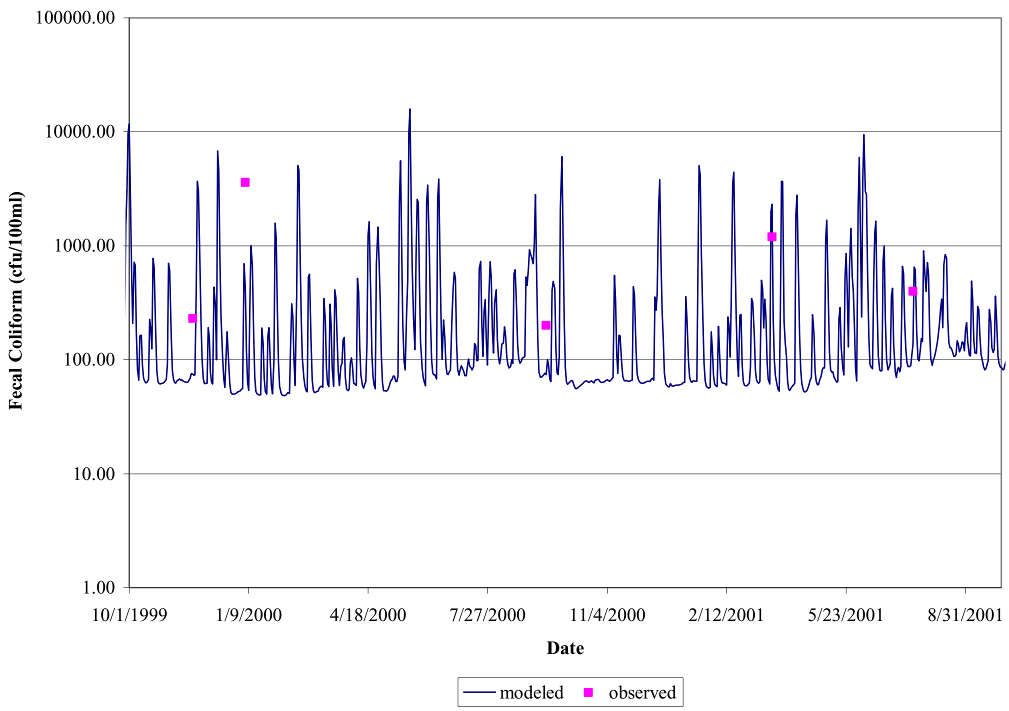

Figure C. 4 Quality validation results for period 10/1/1999 to 9/30/2001 Slate River, subshed 10 VADEQ Station 2-SLT003.68.

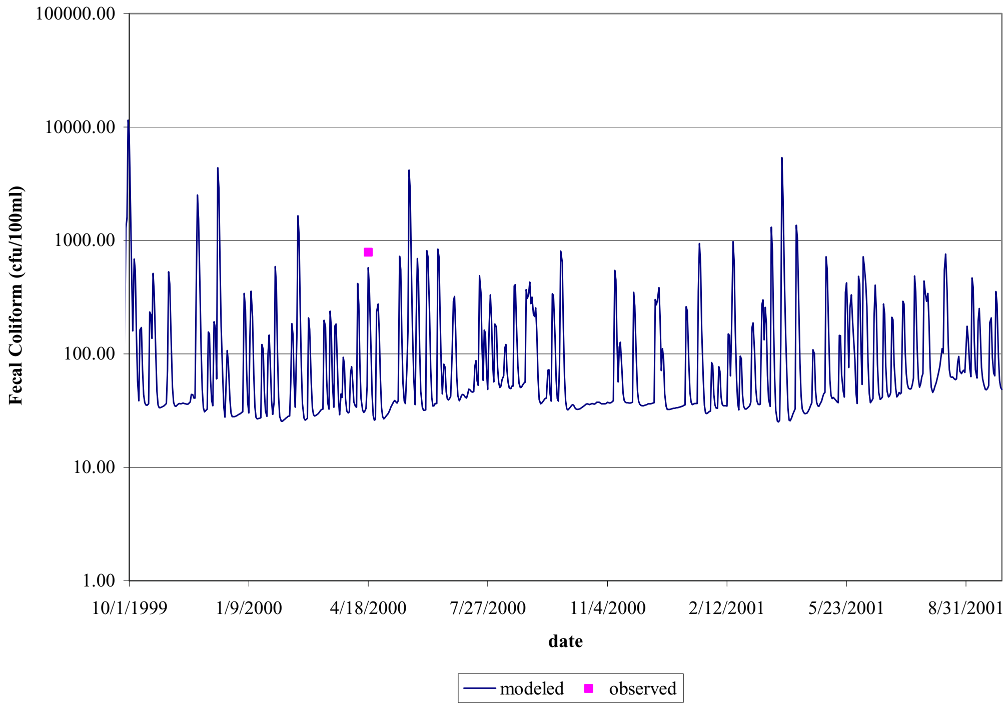

Figure C. 5 Quality validation results for period 10/1/1999 to 9/30/2001 Troublesome Creek, subshed 17 VADEQ Station 2-TBM000.80.

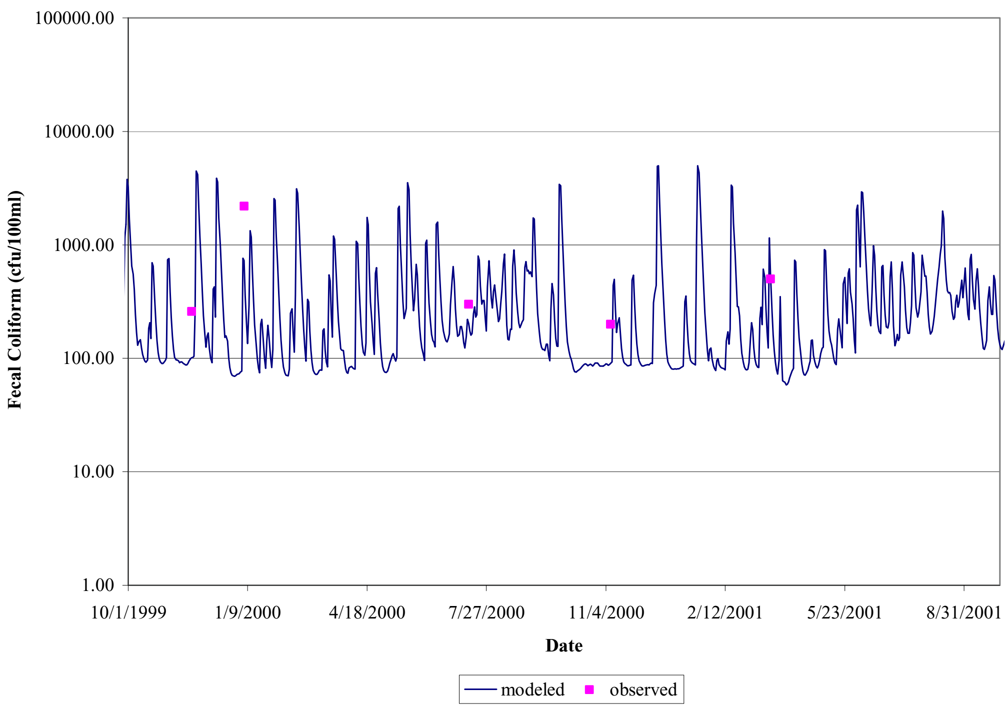

Figure C. 6 Quality validation results for period 10/1/1999 to 9/30/2001 Rock Island Creek, subshed 34 VADEQ Station 2-RKI003.40.

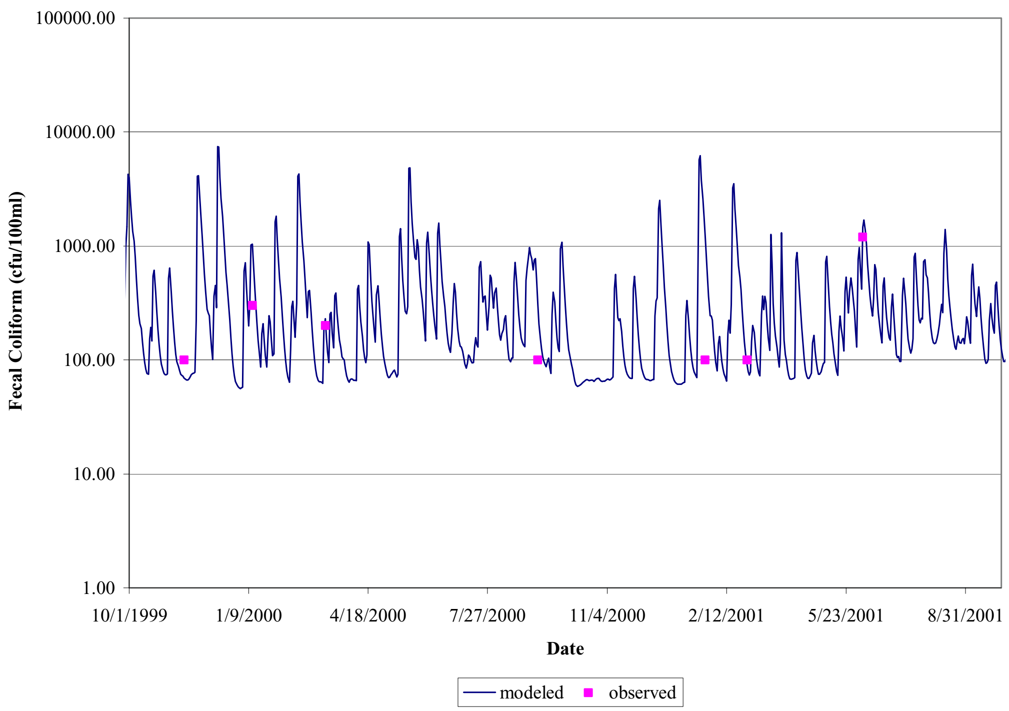

Figure C. 7 Quality validation results for period 10/1/1999 to 9/30/2001 Ballinger Creek, subshed 37 VADEQ Station 2-BAL003.00.

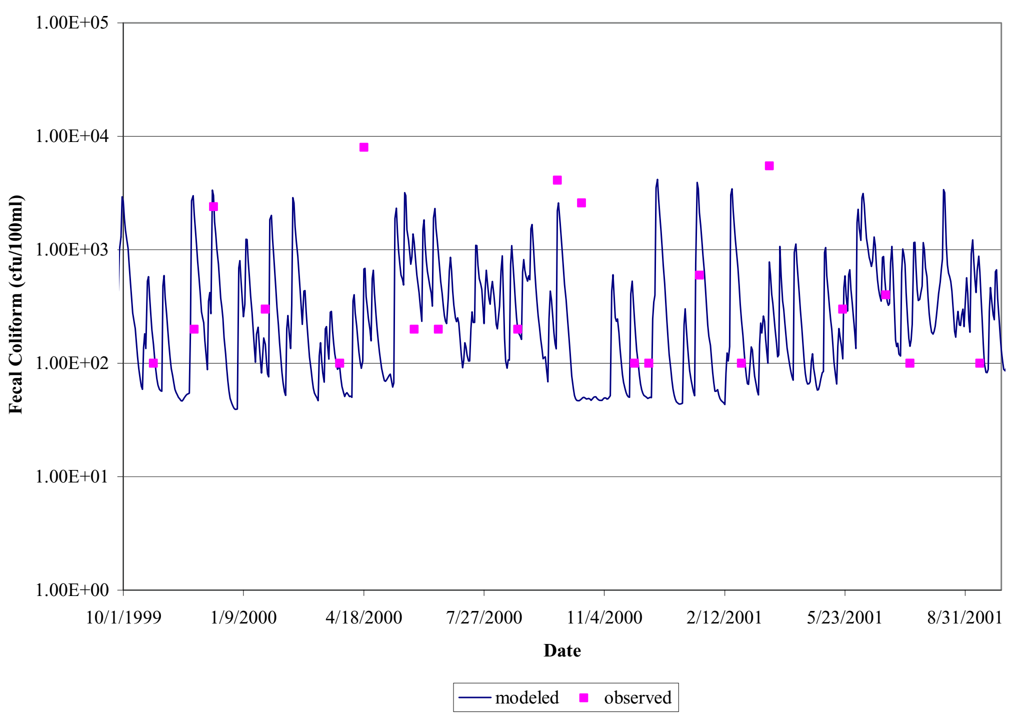

Figure C. 8 Quality validation results for period 10/1/1999 to 9/30/2001 Totier Creek, subshed 39 VADEQ Station 2-TOT002.61.

APPENDIX D

Concentration – Discharge by Water Quality Monitoring Station

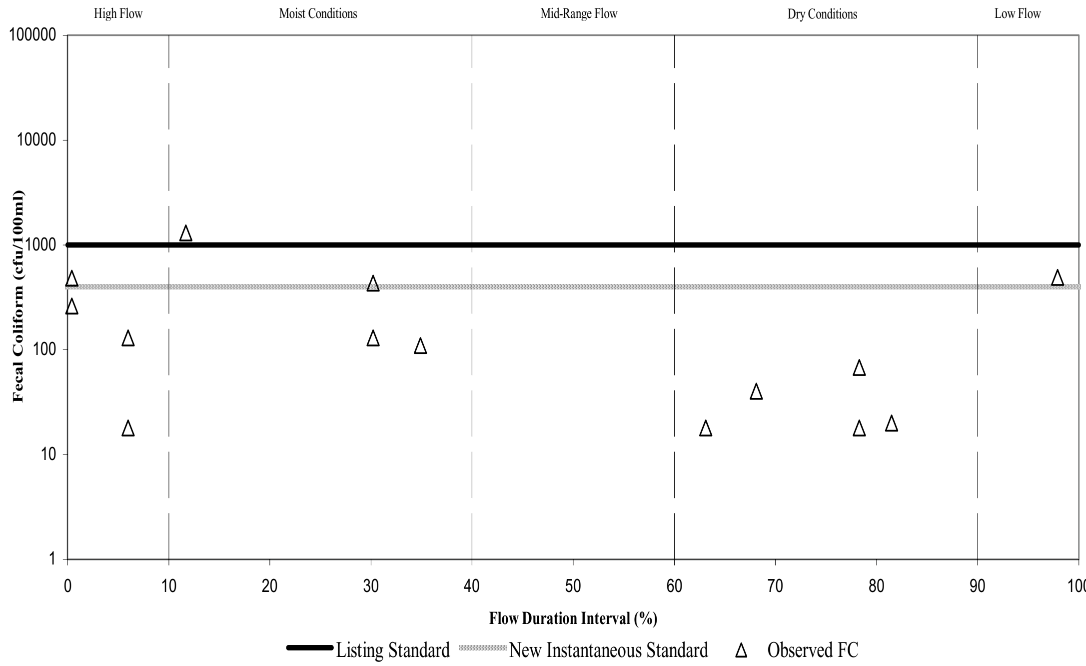

Figure D. 1 Relationship between fecal coliform concentrations (VADEQ Station 2-AUS001.12) and discharge (USGS Gaging Station # 02030000) in the Austin Creek impairment.

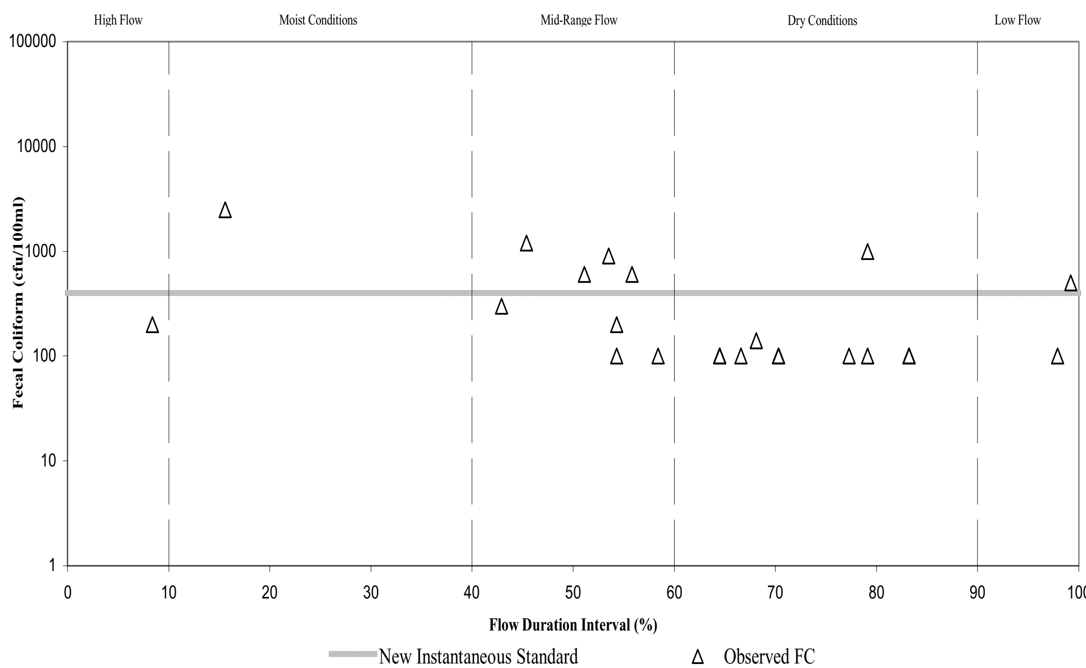

Figure D. 2 Relationship between fecal coliform concentrations (VADEQ Station 2-BLR003.00) and discharge (USGS Gaging Station #02030000) in the Ballinger Creek impairment.

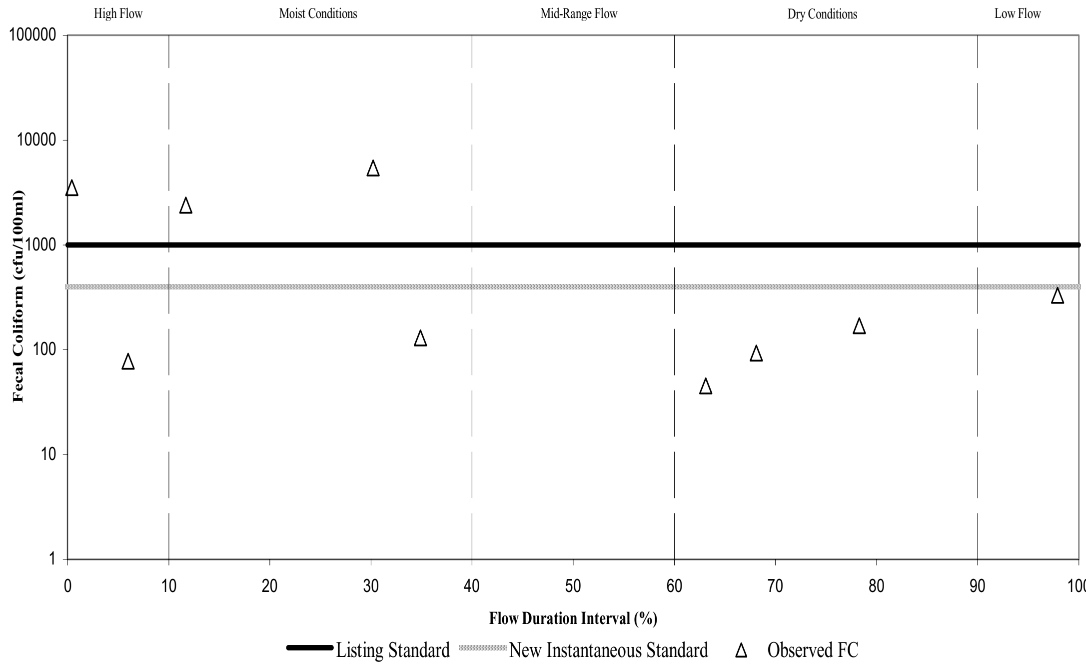

Figure D. 3 Relationship between fecal coliform concentrations (VADEQ Station 2-FRY000.35) and discharge (USGS Gaging Station #02030000) in the Frisby Branch impairment.

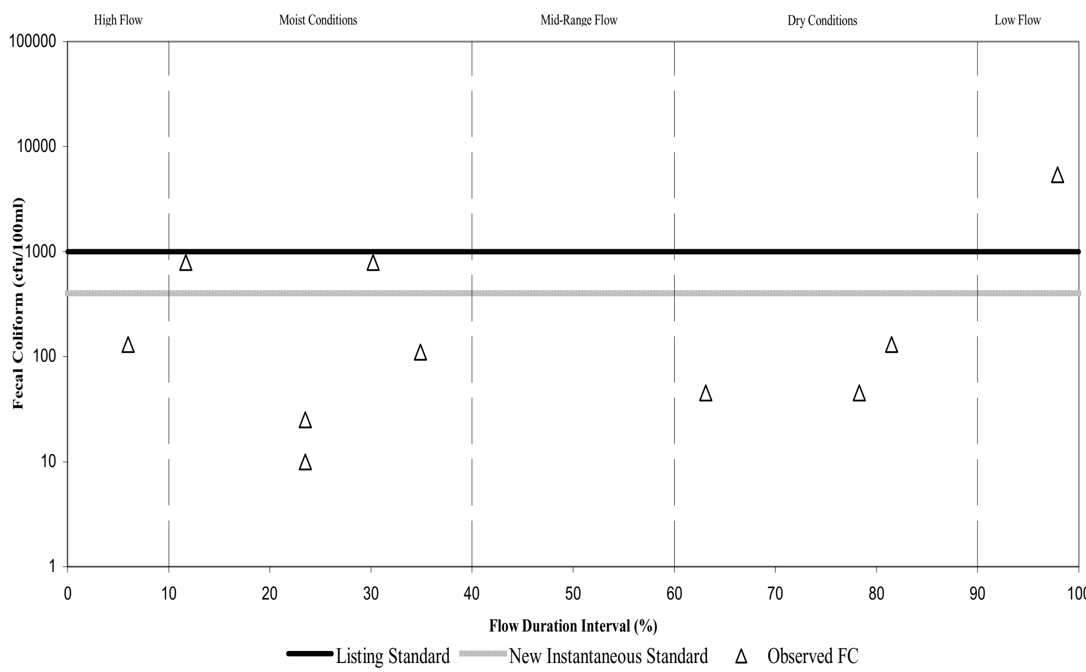

Figure D. 4 Relationship between fecal coliform concentrations (VADEQ Station 2-FRY003.00) and discharge (USGS Gaging Station #02030000) in the Frisby Branch impairment.

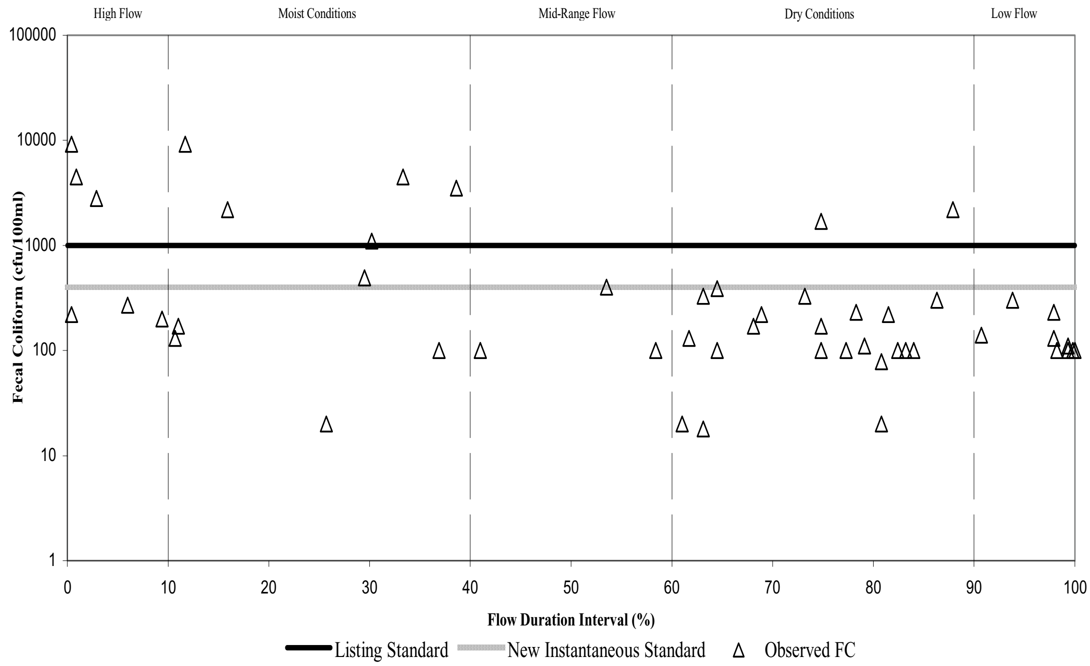

Figure D. 5 Relationship between fecal coliform concentrations (VADEQ Station 2-NTH001.65) and discharge (USGS Gaging Station #02030000) in the North River impairment.

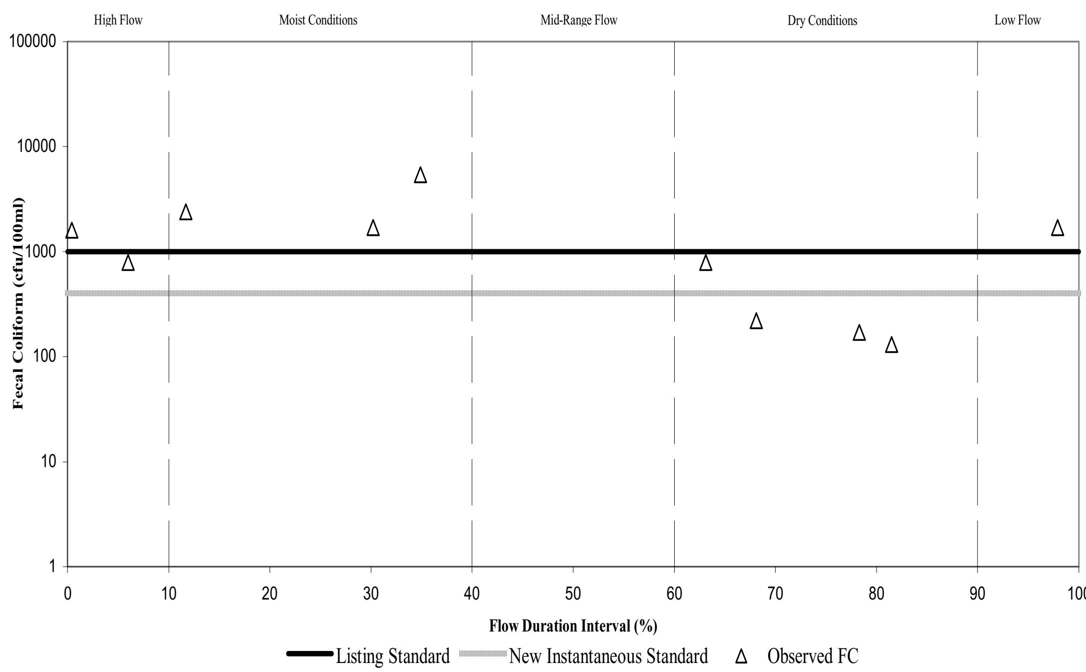

Figure D. 6 Relationship between fecal coliform concentrations (VADEQ Station 2-NTH003.00) and discharge (USGS Gaging Station #02030000) in the North River impairment.

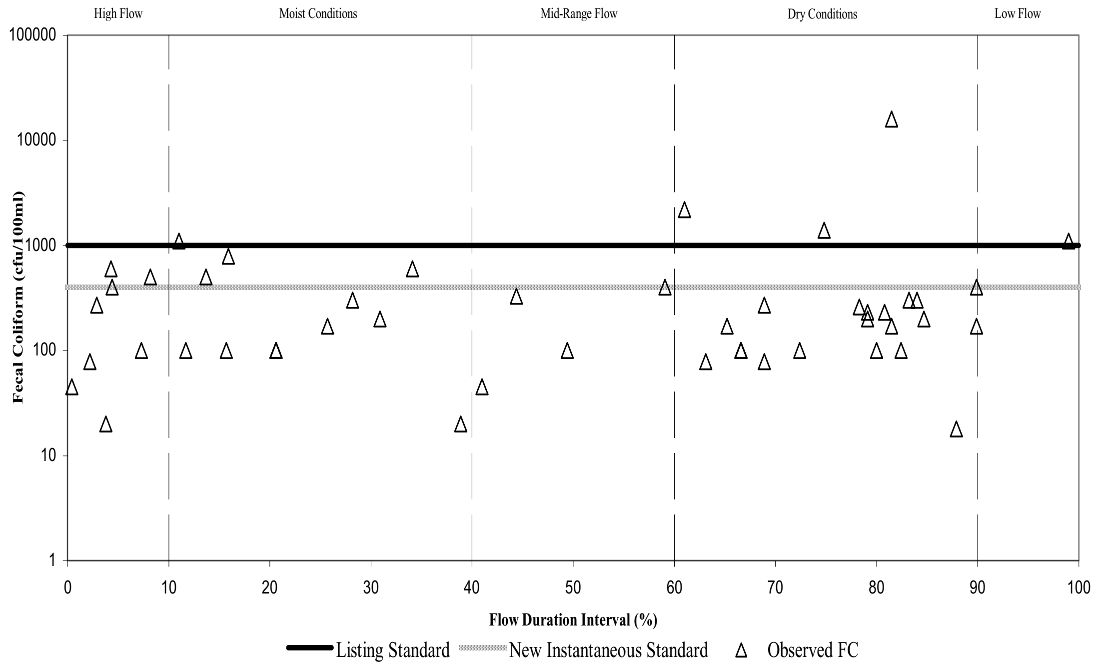

Figure D. 7 Relationship between fecal coliform concentrations (VADEQ Station 2-RKI003.40) and discharge (USGS Gaging Station #02030000) in the Rock Island Creek impairment.

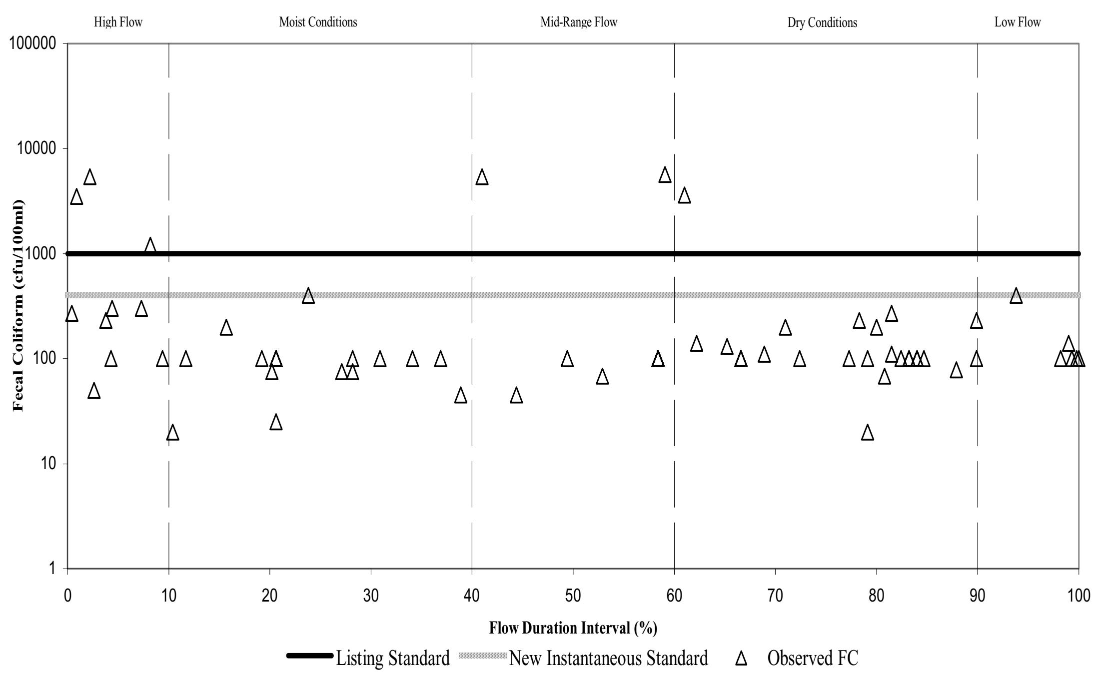

Figure D. 8 Relationship between fecal coliform concentrations (VADEQ Station 2-SLT003.68) and discharge (USGS Gaging Station #02030000) in the Slate Creek impairment.

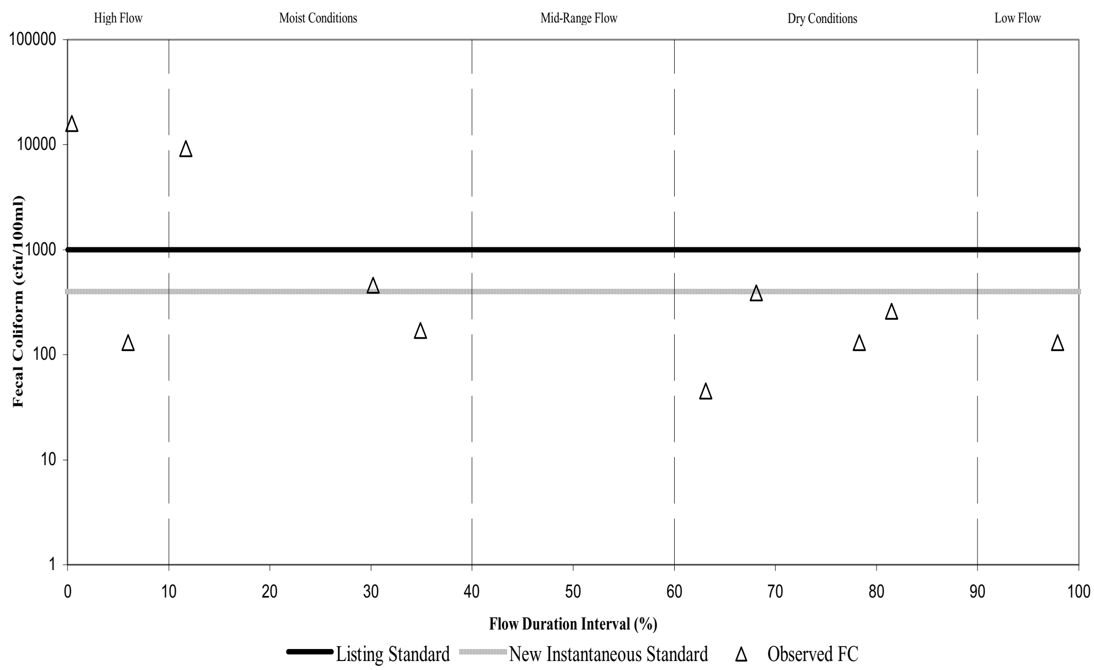

Figure D. 9 **Relationship between fecal coliform concentrations (VADEQ Station 2-SLT024.72) and discharge (USGS Gaging Station #02030000) in the Slate Creek impairment.**

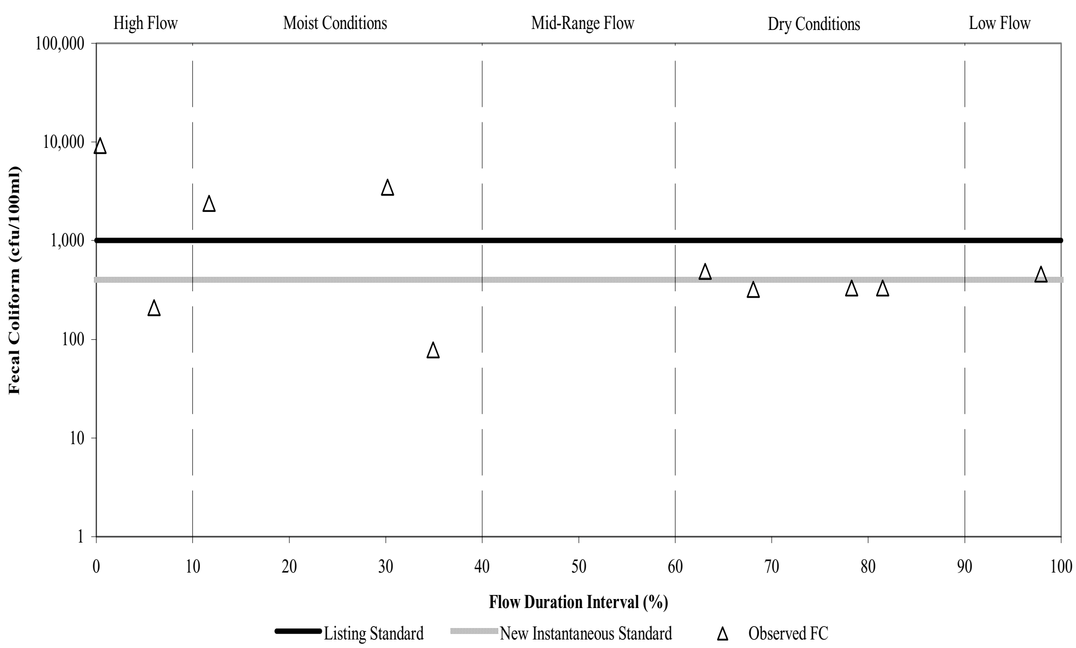

Figure D. 10 **Relationship between fecal coliform concentrations (VADEQ Station 2-SLT030.19) and discharge (USGS Gaging Station #02030000) in the Slate Creek impairment.**

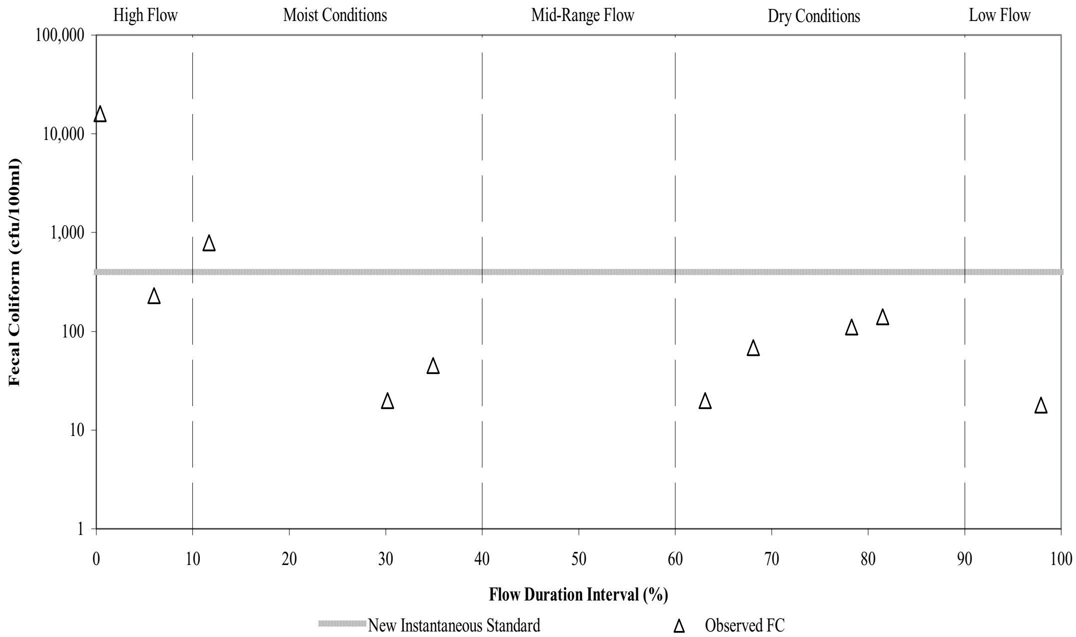

Figure D. 11 Relationship between fecal coliform concentrations (VADEQ Station 2-TBM000.80) and discharge (USGS Gaging Station #02030000) in the Troublesome Creek impairment.

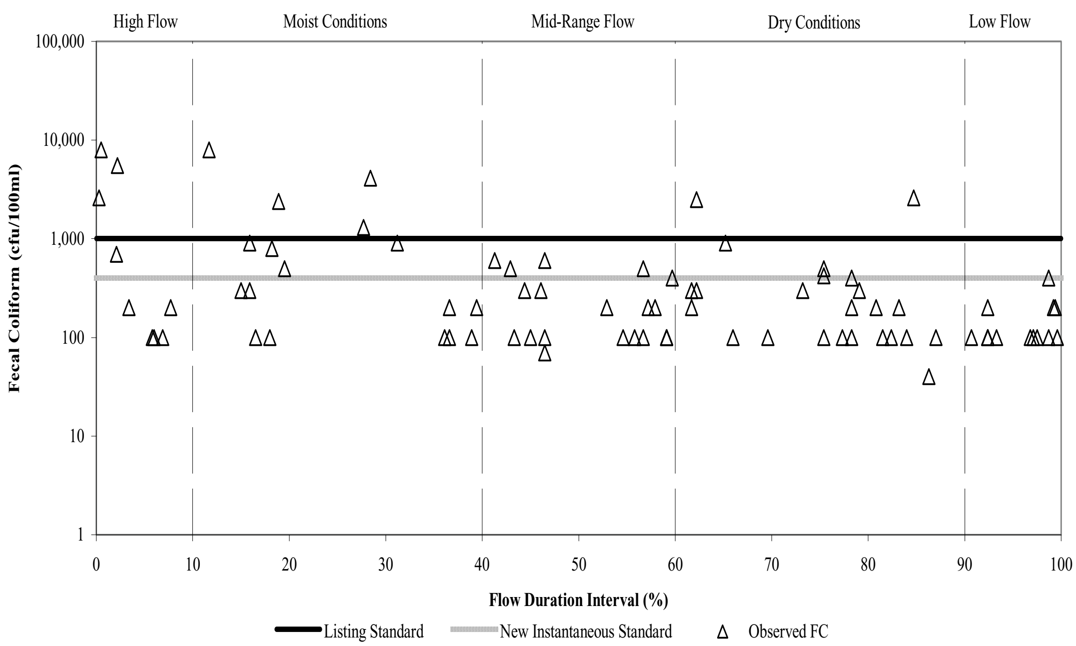

Figure D. 12 Relationship between fecal coliform concentrations (VADEQ Station 2-TOT002.61) and discharge (USGS Gaging Station #02030000) in the Totier Creek impairment.

APPENDIX E

FECAL COLIFORM LOADS IN EXISTING CONDITIONS

Table E.1 Current conditions of land applied *E. coli* load by land use for the Austin Creek watershed (subwatershed 13).

Month	Barren	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	1.99E+11	4.18E+12	2.43E+10	2.08E+11	1.57E+12	7.54E+09	6.72E+11
February	1.79E+11	3.77E+12	2.20E+10	1.85E+11	1.42E+12	6.81E+09	6.07E+11
March	1.99E+11	4.18E+12	3.47E+10	1.98E+11	3.23E+13	7.54E+09	6.72E+11
April	1.92E+11	4.04E+12	4.69E+10	1.89E+11	3.22E+13	7.30E+09	6.50E+11
May	1.99E+11	4.18E+12	4.84E+10	1.92E+11	3.23E+13	7.54E+09	6.72E+11
June	1.92E+11	4.04E+12	5.69E+10	1.83E+11	1.68E+13	7.30E+09	6.50E+11
July	1.99E+11	4.18E+12	5.88E+10	1.83E+11	1.69E+13	7.54E+09	6.72E+11
August	1.99E+11	4.18E+12	5.88E+10	1.83E+11	1.69E+13	7.54E+09	6.72E+11
September	1.92E+11	4.04E+12	4.69E+10	1.77E+11	1.69E+13	7.30E+09	6.50E+11
October	1.99E+11	4.18E+12	3.47E+10	1.80E+11	1.56E+12	7.54E+09	6.72E+11
November	1.92E+11	4.04E+12	3.35E+10	1.77E+11	1.51E+12	7.30E+09	6.50E+11
December	1.99E+11	4.18E+12	2.43E+10	1.95E+11	1.57E+12	7.54E+09	6.72E+11
Annual Total Loads (cfu/yr)	**2.34E+12**	**4.92E+13**	**4.90E+11**	**2.25E+12**	**1.72E+14**	**8.88E+10**	**7.91E+12**

Table E.2 Current conditions of land applied *E. coli* load by land use for the Ballinger Creek watershed (subwatersheds 37 & 38).

Month	Barren	Commercial	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	6.44E+10	2.59E+08	9.17E+12	9.05E+11	1.91E+12	4.48E+13	2.40E+11	2.99E+11
February	5.82E+10	2.34E+08	8.28E+12	8.17E+11	1.70E+12	4.05E+13	2.17E+11	2.70E+11
March	6.44E+10	2.59E+08	9.17E+12	1.10E+12	1.82E+12	4.46E+13	2.40E+11	2.99E+11
April	6.24E+10	2.51E+08	8.87E+12	1.33E+12	1.73E+12	4.27E+13	2.32E+11	2.90E+11
May	6.44E+10	2.59E+08	9.17E+12	1.37E+12	1.76E+12	4.42E+13	2.40E+11	2.99E+11
June	6.24E+10	2.51E+08	8.87E+12	1.52E+12	1.68E+12	4.25E+13	2.32E+11	2.90E+11
July	6.44E+10	2.59E+08	9.17E+12	1.57E+12	1.67E+12	4.39E+13	2.40E+11	2.99E+11
August	6.44E+10	2.59E+08	9.17E+12	1.57E+12	1.67E+12	4.39E+13	2.40E+11	2.99E+11
September	6.24E+10	2.51E+08	8.87E+12	1.33E+12	1.62E+12	4.27E+13	2.32E+11	2.90E+11
October	6.44E+10	2.59E+08	9.17E+12	1.10E+12	1.64E+12	4.46E+13	2.40E+11	2.99E+11
November	6.24E+10	2.51E+08	8.87E+12	1.07E+12	1.62E+12	4.31E+13	2.32E+11	2.90E+11
December	6.44E+10	2.59E+08	9.17E+12	9.05E+11	1.79E+12	4.48E+13	2.40E+11	2.99E+11
Annual Total Loads (cfu/yr)	**7.59E+11**	**3.05E+09**	**1.08E+14**	**1.46E+13**	**2.06E+13**	**5.22E+14**	**2.82E+12**	**3.53E+12**

Table E.3 Current conditions of land applied *E. coli* load by land use for the Frisby Branch watershed (subwatershed 2).

Month	Barren	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	1.41E+11	3.11E+12	1.07E+11	3.88E+11	5.60E+12	3.57E+10	1.81E+11
February	1.27E+11	2.81E+12	9.65E+10	3.46E+11	5.06E+12	3.23E+10	1.64E+11
March	1.41E+11	3.11E+12	1.43E+11	3.72E+11	6.70E+13	3.57E+10	1.81E+11
April	1.36E+11	3.01E+12	1.85E+11	3.55E+11	6.68E+13	3.46E+10	1.76E+11
May	1.41E+11	3.11E+12	1.92E+11	3.61E+11	6.70E+13	3.57E+10	1.81E+11
June	1.36E+11	3.01E+12	2.20E+11	3.45E+11	3.60E+13	3.46E+10	1.76E+11
July	1.41E+11	3.11E+12	2.28E+11	3.45E+11	3.62E+13	3.57E+10	1.81E+11
August	1.41E+11	3.11E+12	2.28E+11	3.45E+11	3.62E+13	3.57E+10	1.81E+11
September	1.36E+11	3.01E+12	1.85E+11	3.34E+11	3.60E+13	3.46E+10	1.76E+11
October	1.41E+11	3.11E+12	1.43E+11	3.40E+11	5.55E+12	3.57E+10	1.81E+11
November	1.36E+11	3.01E+12	1.39E+11	3.34E+11	5.37E+12	3.46E+10	1.76E+11
December	1.41E+11	3.11E+12	1.07E+11	3.67E+11	5.60E+12	3.57E+10	1.81E+11
Annual Total Loads (cfu/yr)	**1.66E+12**	**3.66E+13**	**1.97E+12**	**4.23E+12**	**3.72E+14**	**4.21E+11**	**2.14E+12**

Table E.4 Current conditions of land applied *E. coli* load by land use for the North River watershed (subwatersheds 13,14,15,16 & 22).

Month	Barren	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	7.68E+11	2.11E+13	1.08E+12	1.52E+12	5.93E+13	1.48E+11	2.68E+12
February	6.94E+11	1.90E+13	9.73E+11	1.35E+12	5.35E+13	1.34E+11	2.42E+12
March	7.68E+11	2.11E+13	1.46E+12	1.45E+12	6.90E+14	1.48E+11	2.68E+12
April	7.43E+11	2.04E+13	1.91E+12	1.38E+12	6.87E+14	1.43E+11	2.59E+12
May	7.68E+11	2.11E+13	1.98E+12	1.40E+12	6.89E+14	1.48E+11	2.68E+12
June	7.43E+11	2.04E+13	2.28E+12	1.33E+12	3.71E+14	1.43E+11	2.59E+12
July	7.68E+11	2.11E+13	2.36E+12	1.33E+12	3.73E+14	1.48E+11	2.68E+12
August	7.68E+11	2.11E+13	2.36E+12	1.33E+12	3.73E+14	1.48E+11	2.68E+12
September	7.43E+11	2.04E+13	1.91E+12	1.29E+12	3.72E+14	1.43E+11	2.59E+12
October	7.68E+11	2.11E+13	1.46E+12	1.31E+12	5.87E+13	1.48E+11	2.68E+12
November	7.43E+11	2.04E+13	1.42E+12	1.29E+12	5.68E+13	1.43E+11	2.59E+12
December	7.68E+11	2.11E+13	1.08E+12	1.43E+12	5.93E+13	1.48E+11	2.68E+12
Annual Total Loads (cfu/yr)	**9.04E+12**	**2.48E+14**	**2.03E+13**	**1.64E+13**	**3.84E+15**	**1.74E+12**	**3.16E+13**

Table E.5 Current conditions of land applied *E. coli* load by land use for the Rock Island Creek watershed (subwatersheds 34,35 & 36).

Month	Barren	Commercial	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	4.24E+11	7.36E+07	1.30E+13	3.58E+11	1.73E+12	1.98E+13	6.28E+10	8.78E+11
February	3.83E+11	6.65E+07	1.17E+13	3.23E+11	1.54E+12	1.78E+13	5.67E+10	7.93E+11
March	4.24E+11	7.36E+07	1.30E+13	4.87E+11	1.67E+12	1.96E+13	6.28E+10	8.78E+11
April	4.11E+11	7.12E+07	1.25E+13	6.37E+11	1.59E+12	1.87E+13	6.08E+10	8.49E+11
May	4.24E+11	7.36E+07	1.30E+13	6.58E+11	1.62E+12	1.93E+13	6.28E+10	8.78E+11
June	4.11E+11	7.12E+07	1.25E+13	7.62E+11	1.55E+12	1.85E+13	6.08E+10	8.49E+11
July	4.24E+11	7.36E+07	1.30E+13	7.87E+11	1.56E+12	1.91E+13	6.28E+10	8.78E+11
August	4.24E+11	7.36E+07	1.30E+13	7.87E+11	1.56E+12	1.91E+13	6.28E+10	8.78E+11
September	4.11E+11	7.12E+07	1.25E+13	6.37E+11	1.51E+12	1.87E+13	6.08E+10	8.49E+11
October	4.24E+11	7.36E+07	1.30E+13	4.87E+11	1.54E+12	1.96E+13	6.28E+10	8.78E+11
November	4.11E+11	7.12E+07	1.25E+13	4.71E+11	1.51E+12	1.89E+13	6.08E+10	8.49E+11
December	4.24E+11	7.36E+07	1.30E+13	3.58E+11	1.64E+12	1.98E+13	6.28E+10	8.78E+11
Annual Total Loads (cfu/yr)	**5.00E+12**	**8.67E+08**	**1.53E+14**	**6.75E+12**	**1.90E+13**	**2.29E+14**	**7.40E+11**	**1.03E+13**

Table E.6 Current conditions of land applied *E. coli* load by land use for the Lower Slate River watershed (subwatersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27, 28,29,30,31,32 & 33).

Month	Barren	Commercial	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	5.39E+12	8.01E+10	1.49E+14	7.81E+12	1.74E+13	4.08E+14	1.15E+12	1.07E+13
February	4.87E+12	7.23E+10	1.35E+14	7.06E+12	1.55E+13	3.68E+14	1.04E+12	9.66E+12
March	5.39E+12	8.01E+10	1.49E+14	1.05E+13	1.66E+13	2.14E+15	8.71E+14	1.07E+13
April	5.21E+12	7.75E+10	1.44E+14	1.35E+13	1.58E+13	2.13E+15	8.71E+14	1.04E+13
May	5.39E+12	8.01E+10	1.49E+14	1.40E+13	1.61E+13	2.14E+15	2.19E+14	1.07E+13
June	5.21E+12	7.75E+10	1.44E+14	1.61E+13	1.53E+13	1.47E+15	1.11E+12	1.04E+13
July	5.39E+12	8.01E+10	1.49E+14	1.66E+13	1.53E+13	1.48E+15	1.15E+12	1.07E+13
August	5.39E+12	8.01E+10	1.49E+14	1.66E+13	1.53E+13	1.48E+15	1.15E+12	1.07E+13
September	5.21E+12	7.75E+10	1.44E+14	1.35E+13	1.48E+13	1.26E+15	8.71E+14	1.04E+13
October	5.39E+12	8.01E+10	1.49E+14	1.05E+13	1.50E+13	4.04E+14	6.54E+14	1.07E+13
November	5.21E+12	7.75E+10	1.44E+14	1.01E+13	1.48E+13	3.91E+14	2.19E+14	1.04E+13
December	5.39E+12	8.01E+10	1.49E+14	7.81E+12	1.64E+13	4.08E+14	1.15E+12	1.07E+13
Annual Total Loads (cfu/yr)	**6.34E+13**	**9.43E+11**	**1.76E+15**	**1.44E+14**	**1.88E+14**	**1.41E+16**	**3.71E+15**	**1.26E+14**

Table E.7 Current conditions of land applied *E. coli* load by land use for the Upper Slate River watershed (subwatersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 21,22 & 23).

Month	Barren	Commercial	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	2.18E+12	3.39E+10	6.76E+13	3.11E+12	7.51E+12	1.71E+14	5.27E+11	6.48E+12
February	1.97E+12	3.07E+10	6.11E+13	2.81E+12	6.68E+12	1.54E+14	4.76E+11	5.86E+12
March	2.18E+12	3.39E+10	6.76E+13	4.22E+12	7.16E+12	1.43E+15	6.77E+14	6.48E+12
April	2.11E+12	3.29E+10	6.54E+13	5.51E+12	6.81E+12	1.42E+15	6.77E+14	6.27E+12
May	2.18E+12	3.39E+10	6.76E+13	5.69E+12	6.92E+12	1.43E+15	1.70E+14	6.48E+12
June	2.11E+12	3.29E+10	6.54E+13	6.58E+12	6.58E+12	9.60E+14	5.10E+11	6.27E+12
July	2.18E+12	3.39E+10	6.76E+13	6.80E+12	6.56E+12	9.65E+14	5.27E+11	6.48E+12
August	2.18E+12	3.39E+10	6.76E+13	6.80E+12	6.56E+12	9.65E+14	5.27E+11	6.48E+12
September	2.11E+12	3.29E+10	6.54E+13	5.51E+12	6.35E+12	7.92E+14	6.77E+14	6.27E+12
October	2.18E+12	3.39E+10	6.76E+13	4.22E+12	6.45E+12	1.69E+14	5.08E+14	6.48E+12
November	2.11E+12	3.29E+10	6.54E+13	4.08E+12	6.35E+12	1.63E+14	1.70E+14	6.27E+12
December	2.18E+12	3.39E+10	6.76E+13	3.11E+12	7.04E+12	1.71E+14	5.27E+11	6.48E+12
Annual Total Loads (cfu/yr)	**2.56E+13**	**4.00E+11**	**7.96E+14**	**5.85E+13**	**8.10E+13**	**8.79E+15**	**2.88E+15**	**7.63E+13**

Table E.8 Current conditions of land applied *E. coli* load by land use for the Totier Creek watershed (subwatersheds 39,40 & 41).

Month	Barren	Commercial	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	2.89E+11	3.12E+09	1.35E+13	1.23E+12	3.22E+12	8.05E+13	4.95E+11	1.08E+12
February	2.61E+11	2.82E+09	1.22E+13	1.11E+12	2.86E+12	7.28E+13	4.47E+11	9.77E+11
March	2.89E+11	3.12E+09	1.35E+13	1.41E+12	3.06E+12	8.03E+13	4.95E+11	1.08E+12
April	2.80E+11	3.02E+09	1.31E+13	1.61E+12	2.90E+12	7.73E+13	4.79E+11	1.05E+12
May	2.89E+11	3.12E+09	1.35E+13	1.66E+12	2.95E+12	7.99E+13	4.95E+11	1.08E+12
June	2.80E+11	3.02E+09	1.31E+13	1.79E+12	2.80E+12	7.71E+13	4.79E+11	1.05E+12
July	2.89E+11	3.12E+09	1.35E+13	1.85E+12	2.78E+12	7.97E+13	4.95E+11	1.08E+12
August	2.89E+11	3.12E+09	1.35E+13	1.85E+12	2.78E+12	7.97E+13	4.95E+11	1.08E+12
September	2.80E+11	3.02E+09	1.31E+13	1.61E+12	2.69E+12	7.73E+13	4.79E+11	1.05E+12
October	2.89E+11	3.12E+09	1.35E+13	1.41E+12	2.73E+12	8.03E+13	4.95E+11	1.08E+12
November	2.80E+11	3.02E+09	1.31E+13	1.37E+12	2.69E+12	7.77E+13	4.79E+11	1.05E+12
December	2.89E+11	3.12E+09	1.35E+13	1.23E+12	3.00E+12	8.05E+13	4.95E+11	1.08E+12
Annual Total Loads (cfu/yr)	**3.41E+12**	**3.67E+10**	**1.59E+14**	**1.81E+13**	**3.45E+13**	**9.43E+14**	**5.83E+12**	**1.27E+13**

Table E.9 Current conditions of land applied *E. coli* load by land use for the Troublesome Creek watershed (subwatersheds 17 & 23).

Month	Barren	Commercial	Forest	Livestock Access	Residential	Pasture	Cropland	Wetlands
January	1.52E+11	1.82E+10	4.48E+12	2.39E+11	1.51E+12	1.32E+13	5.41E+10	2.13E+11
February	1.38E+11	1.64E+10	4.05E+12	2.15E+11	1.34E+12	1.20E+13	4.88E+10	1.93E+11
March	1.52E+11	1.82E+10	4.48E+12	3.24E+11	1.44E+12	8.78E+13	2.90E+14	2.13E+11
April	1.47E+11	1.76E+10	4.34E+12	4.24E+11	1.37E+12	8.72E+13	2.90E+14	2.06E+11
May	1.52E+11	1.82E+10	4.48E+12	4.38E+11	1.39E+12	8.77E+13	7.26E+13	2.13E+11
June	1.47E+11	1.76E+10	4.34E+12	5.06E+11	1.32E+12	1.22E+14	5.23E+10	2.06E+11
July	1.52E+11	1.82E+10	4.48E+12	5.23E+11	1.32E+12	1.23E+14	5.41E+10	2.13E+11
August	1.52E+11	1.82E+10	4.48E+12	5.23E+11	1.32E+12	1.23E+14	5.41E+10	2.13E+11
September	1.47E+11	1.76E+10	4.34E+12	4.24E+11	1.28E+12	4.99E+13	2.90E+14	2.06E+11
October	1.52E+11	1.82E+10	4.48E+12	3.24E+11	1.30E+12	1.31E+13	2.18E+14	2.13E+11
November	1.47E+11	1.76E+10	4.34E+12	3.14E+11	1.28E+12	1.27E+13	7.26E+13	2.06E+11
December	1.52E+11	1.82E+10	4.48E+12	2.39E+11	1.42E+12	1.32E+13	5.41E+10	2.13E+11
Annual Total Loads (cfu/yr)	**1.79E+12**	**2.14E+11**	**5.28E+13**	**4.49E+12**	**1.63E+13**	**7.45E+14**	**1.23E+15**	**2.51E+12**

Table E.10 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Austin Creek watershed (subwatershed 13).

Reach ID	Source Type	January	February	March	April	May	June
13	Human	2.25E+11	2.03E+11	2.25E+11	2.18E+11	2.25E+11	2.18E+11
13	Livestock	1.03E+10	9.33E+09	1.48E+10	2.00E+10	2.07E+10	2.43E+10
13	Wildlife	9.71E+10	8.77E+10	9.71E+10	9.40E+10	9.71E+10	9.40E+10

Table E.11 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Austin Creek watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
13	Human	2.25E+11	2.25E+11	2.18E+11	2.25E+11	2.18E+11	2.25E+11
13	Livestock	2.51E+10	2.51E+10	2.00E+10	1.48E+10	1.43E+10	1.03E+10
13	Wildlife	9.71E+10	9.71E+10	9.40E+10	9.71E+10	9.40E+10	9.71E+10

Table E.12 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Ballinger Creek watershed (subwatersheds 37 & 38).

Reach ID	Source Type	January	February	March	April	May	June
37	Human	9.14E+11	8.26E+11	9.14E+11	8.85E+11	9.14E+11	8.85E+11
37	Livestock	1.31E+11	1.18E+11	1.87E+11	2.53E+11	2.62E+11	3.07E+11
37	Wildlife	2.18E+11	1.96E+11	2.18E+11	2.11E+11	2.18E+11	2.11E+11
38	Human	2.46E+11	2.22E+11	2.46E+11	2.38E+11	2.46E+11	2.38E+11
38	Livestock	6.87E+10	6.21E+10	9.82E+10	1.33E+11	1.37E+11	1.61E+11
38	Wildlife	5.60E+10	5.06E+10	5.60E+10	5.42E+10	5.60E+10	5.42E+10

Table E.13 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Ballinger Creek watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
37	Human	9.14E+11	9.14E+11	8.85E+11	9.14E+11	8.85E+11	9.14E+11
37	Livestock	3.18E+11	3.18E+11	2.53E+11	1.87E+11	1.81E+11	1.31E+11
37	Wildlife	2.18E+11	2.18E+11	2.11E+11	2.18E+11	2.11E+11	2.18E+11
38	Human	2.46E+11	2.46E+11	2.38E+11	2.46E+11	2.38E+11	2.46E+11
38	Livestock	1.67E+11	1.67E+11	1.33E+11	9.82E+10	9.50E+10	6.87E+10
38	Wildlife	5.60E+10	5.60E+10	5.42E+10	5.60E+10	5.42E+10	5.60E+10

Table E.14 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Frisby Branch watershed (subwatershed 2).

Reach ID	Source Type	January	February	March	April	May	June
2	Human	3.50E+11	3.16E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11
2	Livestock	3.63E+10	3.28E+10	5.18E+10	7.02E+10	7.26E+10	8.53E+10
2	Wildlife	7.29E+10	6.58E+10	7.29E+10	7.05E+10	7.29E+10	7.05E+10

Table E.15 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Frisby Branch watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
2	Human	3.50E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11	3.50E+11
2	Livestock	8.81E+10	8.81E+10	7.02E+10	5.18E+10	5.02E+10	3.63E+10
2	Wildlife	7.29E+10	7.29E+10	7.05E+10	7.29E+10	7.05E+10	7.29E+10

Table E.16 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the North River watershed (subwatersheds 13,14,15,16 & 22).

Reach ID	Source Type	January	February	March	April	May	June
13	Human	2.25E+11	2.03E+11	2.25E+11	2.18E+11	2.25E+11	2.18E+11
13	Livestock	1.03E+10	9.33E+09	1.48E+10	2.00E+10	2.07E+10	2.43E+10
13	Wildlife	9.71E+10	8.77E+10	9.71E+10	9.40E+10	9.71E+10	9.40E+10
14	Human	2.43E+11	2.20E+11	2.43E+11	2.35E+11	2.43E+11	2.35E+11
14	Livestock	2.18E+11	1.97E+11	3.11E+11	4.21E+11	4.35E+11	5.11E+11
14	Wildlife	9.71E+10	8.77E+10	9.71E+10	9.39E+10	9.71E+10	9.39E+10
15	Human	2.44E+11	2.20E+11	2.44E+11	2.36E+11	2.44E+11	2.36E+11
15	Livestock	1.04E+11	9.35E+10	1.48E+11	2.00E+11	2.07E+11	2.43E+11
15	Wildlife	8.10E+10	7.32E+10	8.10E+10	7.84E+10	8.10E+10	7.84E+10
16	Human	6.22E+10	5.61E+10	6.22E+10	6.01E+10	6.22E+10	6.01E+10
16	Livestock	1.43E+10	1.29E+10	2.04E+10	2.77E+10	2.86E+10	3.36E+10
16	Wildlife	3.37E+10	3.05E+10	3.37E+10	3.26E+10	3.37E+10	3.26E+10
22	Human	6.64E+11	5.99E+11	6.64E+11	6.42E+11	6.64E+11	6.42E+11
22	Livestock	3.93E+10	3.55E+10	5.61E+10	7.60E+10	7.86E+10	9.23E+10
22	Wildlife	2.49E+11	2.25E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11

Table E.17 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the North River watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
13	Human	2.25E+11	2.25E+11	2.18E+11	2.25E+11	2.18E+11	2.25E+11
13	Livestock	2.51E+10	2.51E+10	2.00E+10	1.48E+10	1.43E+10	1.03E+10
13	Wildlife	9.71E+10	9.71E+10	9.40E+10	9.71E+10	9.40E+10	9.71E+10
14	Human	2.43E+11	2.43E+11	2.35E+11	2.43E+11	2.35E+11	2.43E+11
14	Livestock	5.29E+11	5.29E+11	4.21E+11	3.11E+11	3.01E+11	2.18E+11
14	Wildlife	9.71E+10	9.71E+10	9.39E+10	9.71E+10	9.39E+10	9.71E+10
15	Human	2.44E+11	2.44E+11	2.36E+11	2.44E+11	2.36E+11	2.44E+11
15	Livestock	2.52E+11	2.52E+11	2.00E+11	1.48E+11	1.43E+11	1.04E+11
15	Wildlife	8.10E+10	8.10E+10	7.84E+10	8.10E+10	7.84E+10	8.10E+10
16	Human	6.22E+10	6.22E+10	6.01E+10	6.22E+10	6.01E+10	6.22E+10
16	Livestock	3.47E+10	3.47E+10	2.77E+10	2.04E+10	1.98E+10	1.43E+10
16	Wildlife	3.37E+10	3.37E+10	3.26E+10	3.37E+10	3.26E+10	3.37E+10
22	Human	6.64E+11	6.64E+11	6.42E+11	6.64E+11	6.42E+11	6.64E+11
22	Livestock	9.54E+10	9.54E+10	7.60E+10	5.61E+10	5.43E+10	3.93E+10
22	Wildlife	2.49E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11	2.49E+11

Table E.18 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Rock Island Creek watershed (subwatersheds 34,35 & 36).

Reach ID	Source Type	January	February	March	April	May	June
34	Human	6.41E+11	5.79E+11	6.41E+11	6.20E+11	6.41E+11	6.20E+11
34	Livestock	3.70E+10	3.35E+10	5.29E+10	7.17E+10	7.41E+10	8.71E+10
34	Wildlife	1.28E+11	1.16E+11	1.28E+11	1.24E+11	1.28E+11	1.24E+11
35	Human	2.41E+11	2.18E+11	2.41E+11	2.34E+11	2.41E+11	2.34E+11
35	Livestock	2.21E+10	2.00E+10	3.16E+10	4.29E+10	4.43E+10	5.20E+10
35	Wildlife	5.44E+10	4.92E+10	5.44E+10	5.27E+10	5.44E+10	5.27E+10
36	Human	5.04E+11	4.55E+11	5.04E+11	4.87E+11	5.04E+11	4.87E+11
36	Livestock	6.95E+10	6.28E+10	9.93E+10	1.34E+11	1.39E+11	1.63E+11
36	Wildlife	1.20E+11	1.08E+11	1.20E+11	1.16E+11	1.20E+11	1.16E+11

Table E.19 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Rock Island Creek watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
34	Human	6.41E+11	6.41E+11	6.20E+11	6.41E+11	6.20E+11	6.41E+11
34	Livestock	9.00E+10	9.00E+10	7.17E+10	5.29E+10	5.12E+10	3.70E+10
34	Wildlife	1.28E+11	1.28E+11	1.24E+11	1.28E+11	1.24E+11	1.28E+11
35	Human	2.41E+11	2.41E+11	2.34E+11	2.41E+11	2.34E+11	2.41E+11
35	Livestock	5.38E+10	5.38E+10	4.29E+10	3.16E+10	3.06E+10	2.21E+10
35	Wildlife	5.44E+10	5.44E+10	5.27E+10	5.44E+10	5.27E+10	5.44E+10
36	Human	5.04E+11	5.04E+11	4.87E+11	5.04E+11	4.87E+11	5.04E+11
36	Livestock	1.69E+11	1.69E+11	1.34E+11	9.93E+10	9.61E+10	6.95E+10
36	Wildlife	1.20E+11	1.20E+11	1.16E+11	1.20E+11	1.16E+11	1.20E+11

Table E.20 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Lower Slate River watershed (subwatersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32 & 33).

Reach ID	Source Type	January	February	March	April	May	June
1	Human	5.77E+11	5.21E+11	5.77E+11	5.58E+11	5.77E+11	5.58E+11
1	Livestock	8.09E+10	7.30E+10	1.16E+11	1.56E+11	1.62E+11	1.90E+11
1	Wildlife	1.97E+11	1.78E+11	1.97E+11	1.91E+11	1.97E+11	1.91E+11
2	Human	3.50E+11	3.16E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11
2	Livestock	3.63E+10	3.28E+10	5.18E+10	7.02E+10	7.26E+10	8.53E+10
2	Wildlife	7.29E+10	6.58E+10	7.29E+10	7.05E+10	7.29E+10	7.05E+10
3	Human	1.95E+11	1.76E+11	1.95E+11	1.88E+11	1.95E+11	1.88E+11
3	Livestock	1.14E+11	1.03E+11	1.63E+11	2.20E+11	2.28E+11	2.68E+11
3	Wildlife	9.39E+10	8.48E+10	9.39E+10	9.08E+10	9.39E+10	9.08E+10
4	Human	2.49E+11	2.25E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11
4	Livestock	4.07E+10	3.68E+10	5.82E+10	7.88E+10	8.15E+10	9.57E+10
4	Wildlife	3.64E+10	3.29E+10	3.64E+10	3.53E+10	3.64E+10	3.53E+10
5	Human	1.63E+11	1.47E+11	1.63E+11	1.57E+11	1.63E+11	1.57E+11
5	Livestock	1.84E+10	1.66E+10	2.63E+10	3.57E+10	3.68E+10	4.33E+10
5	Wildlife	3.23E+10	2.92E+10	3.23E+10	3.13E+10	3.23E+10	3.13E+10
6	Human	3.50E+11	3.16E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11
6	Livestock	5.82E+10	5.26E+10	8.32E+10	1.13E+11	1.16E+11	1.37E+11
6	Wildlife	9.52E+10	8.59E+10	9.52E+10	9.21E+10	9.52E+10	9.21E+10
7	Human	1.52E+12	1.37E+12	1.52E+12	1.47E+12	1.52E+12	1.47E+12
7	Livestock	3.26E+11	2.94E+11	4.66E+11	6.31E+11	6.52E+11	7.66E+11
7	Wildlife	2.84E+11	2.56E+11	2.84E+11	2.74E+11	2.84E+11	2.74E+11
8	Human	7.13E+10	6.44E+10	7.13E+10	6.90E+10	7.13E+10	6.90E+10
8	Livestock	5.73E+09	5.17E+09	8.18E+09	1.11E+10	1.15E+10	1.35E+10
8	Wildlife	6.26E+10	5.65E+10	6.26E+10	6.06E+10	6.26E+10	6.06E+10
9	Human	9.50E+11	8.58E+11	9.50E+11	9.19E+11	9.50E+11	9.19E+11
9	Livestock	5.57E+10	5.03E+10	7.96E+10	1.08E+11	1.11E+11	1.31E+11
9	Wildlife	1.75E+11	1.58E+11	1.75E+11	1.70E+11	1.75E+11	1.70E+11
10	Human	3.57E+11	3.23E+11	3.57E+11	3.46E+11	3.57E+11	3.46E+11
10	Livestock	3.26E+10	2.95E+10	4.66E+10	6.32E+10	6.53E+10	7.67E+10
10	Wildlife	7.39E+10	6.68E+10	7.39E+10	7.15E+10	7.39E+10	7.15E+10
11	Human	2.88E+11	2.60E+11	2.88E+11	2.79E+11	2.88E+11	2.79E+11
11	Livestock	1.75E+10	1.58E+10	2.51E+10	3.40E+10	3.51E+10	4.12E+10
11	Wildlife	5.05E+10	4.56E+10	5.05E+10	4.88E+10	5.05E+10	4.88E+10
12	Human	5.12E+10	4.62E+10	5.12E+10	4.95E+10	5.12E+10	4.95E+10
12	Livestock	2.28E+10	2.06E+10	3.26E+10	4.41E+10	4.56E+10	5.36E+10
12	Wildlife	2.55E+10	2.30E+10	2.55E+10	2.47E+10	2.55E+10	2.47E+10
13	Human	2.25E+11	2.03E+11	2.25E+11	2.18E+11	2.25E+11	2.18E+11
13	Livestock	1.03E+10	9.33E+09	1.48E+10	2.00E+10	2.07E+10	2.43E+10
13	Wildlife	9.71E+10	8.77E+10	9.71E+10	9.40E+10	9.71E+10	9.40E+10
14	Human	2.43E+11	2.20E+11	2.43E+11	2.35E+11	2.43E+11	2.35E+11
14	Livestock	2.18E+11	1.97E+11	3.11E+11	4.21E+11	4.35E+11	5.11E+11
14	Wildlife	9.71E+10	8.77E+10	9.71E+10	9.39E+10	9.71E+10	9.39E+10

Table E.21 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Lower Slate River watershed (cont).

Reach ID	Source Type	January	February	March	April	May	June
15	Human	2.44E+11	2.20E+11	2.44E+11	2.36E+11	2.44E+11	2.36E+11
15	Livestock	1.04E+11	9.35E+10	1.48E+11	2.00E+11	2.07E+11	2.43E+11
15	Wildlife	8.10E+10	7.32E+10	8.10E+10	7.84E+10	8.10E+10	7.84E+10
16	Human	6.22E+10	5.61E+10	6.22E+10	6.01E+10	6.22E+10	6.01E+10
16	Livestock	1.43E+10	1.29E+10	2.04E+10	2.77E+10	2.86E+10	3.36E+10
16	Wildlife	3.37E+10	3.05E+10	3.37E+10	3.26E+10	3.37E+10	3.26E+10
17	Human	4.84E+10	4.38E+10	4.84E+10	4.69E+10	4.84E+10	4.69E+10
17	Livestock	9.53E+09	8.61E+09	1.36E+10	1.84E+10	1.91E+10	2.24E+10
17	Wildlife	1.28E+10	1.16E+10	1.28E+10	1.24E+10	1.28E+10	1.24E+10
18	Human	4.96E+11	4.48E+11	4.96E+11	4.80E+11	4.96E+11	4.80E+11
18	Livestock	1.40E+11	1.26E+11	2.00E+11	2.71E+11	2.80E+11	3.29E+11
18	Wildlife	2.80E+11	2.53E+11	2.80E+11	2.71E+11	2.80E+11	2.71E+11
19	Human	9.87E+10	8.92E+10	9.87E+10	9.55E+10	9.87E+10	9.55E+10
19	Livestock	3.22E+10	2.90E+10	4.59E+10	6.22E+10	6.43E+10	7.56E+10
19	Wildlife	4.71E+10	4.26E+10	4.71E+10	4.56E+10	4.71E+10	4.56E+10
20	Human	9.51E+10	8.59E+10	9.51E+10	9.20E+10	9.51E+10	9.20E+10
20	Livestock	1.83E+10	1.65E+10	2.61E+10	3.54E+10	3.66E+10	4.30E+10
20	Wildlife	2.72E+10	2.46E+10	2.72E+10	2.64E+10	2.72E+10	2.64E+10
21	Human	1.32E+12	1.20E+12	1.32E+12	1.28E+12	1.32E+12	1.28E+12
21	Livestock	1.47E+11	1.33E+11	2.10E+11	2.84E+11	2.93E+11	3.45E+11
21	Wildlife	2.70E+11	2.44E+11	2.70E+11	2.61E+11	2.70E+11	2.61E+11
22	Human	6.64E+11	5.99E+11	6.64E+11	6.42E+11	6.64E+11	6.42E+11
22	Livestock	3.93E+10	3.55E+10	5.61E+10	7.60E+10	7.86E+10	9.23E+10
22	Wildlife	2.49E+11	2.25E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11
23	Human	1.18E+12	1.06E+12	1.18E+12	1.14E+12	1.18E+12	1.14E+12
23	Livestock	7.59E+10	6.86E+10	1.08E+11	1.47E+11	1.52E+11	1.78E+11
23	Wildlife	1.34E+11	1.21E+11	1.34E+11	1.30E+11	1.34E+11	1.30E+11
24	Human	4.97E+11	4.49E+11	4.97E+11	4.81E+11	4.97E+11	4.81E+11
24	Livestock	3.84E+11	3.46E+11	5.48E+11	7.42E+11	7.67E+11	9.02E+11
24	Wildlife	4.17E+11	3.77E+11	4.17E+11	4.03E+11	4.17E+11	4.03E+11
25	Human	2.82E+11	2.55E+11	2.82E+11	2.73E+11	2.82E+11	2.73E+11
25	Livestock	1.32E+11	1.19E+11	1.88E+11	2.55E+11	2.64E+11	3.10E+11
25	Wildlife	1.28E+11	1.16E+11	1.28E+11	1.24E+11	1.28E+11	1.24E+11
26	Human	1.55E+11	1.40E+11	1.55E+11	1.50E+11	1.55E+11	1.50E+11
26	Livestock	1.89E+10	1.70E+10	2.69E+10	3.65E+10	3.77E+10	4.43E+10
26	Wildlife	3.78E+10	3.42E+10	3.78E+10	3.66E+10	3.78E+10	3.66E+10
27	Human	2.04E+12	1.85E+12	2.04E+12	1.98E+12	2.04E+12	1.98E+12
27	Livestock	1.72E+11	1.55E+11	2.45E+11	3.32E+11	3.44E+11	4.04E+11
27	Wildlife	1.81E+11	1.63E+11	1.81E+11	1.75E+11	1.81E+11	1.75E+11
28	Human	6.42E+11	5.80E+11	6.42E+11	6.21E+11	6.42E+11	6.21E+11
28	Livestock	4.73E+10	4.27E+10	6.76E+10	9.15E+10	9.46E+10	1.11E+11
28	Wildlife	8.45E+10	7.63E+10	8.45E+10	8.17E+10	8.45E+10	8.17E+10
29	Human	1.30E+11	1.17E+11	1.30E+11	1.26E+11	1.30E+11	1.26E+11
29	Livestock	9.89E+09	8.93E+09	1.41E+10	1.91E+10	1.98E+10	2.32E+10
29	Wildlife	5.61E+10	5.07E+10	5.61E+10	5.43E+10	5.61E+10	5.43E+10

Table E.22 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Lower Slate River watershed (cont).

Reach ID	Source Type	January	February	March	April	May	June
30	Human	6.93E+11	6.26E+11	6.93E+11	6.70E+11	6.93E+11	6.70E+11
30	Livestock	1.27E+11	1.15E+11	1.82E+11	2.46E+11	2.55E+11	2.99E+11
30	Wildlife	1.80E+11	1.63E+11	1.80E+11	1.75E+11	1.80E+11	1.75E+11
31	Human	2.95E+11	2.67E+11	2.95E+11	2.86E+11	2.95E+11	2.86E+11
31	Livestock	3.08E+10	2.78E+10	4.39E+10	5.95E+10	6.15E+10	7.23E+10
31	Wildlife	3.48E+10	3.15E+10	3.48E+10	3.37E+10	3.48E+10	3.37E+10
32	Human	1.57E+12	1.42E+12	1.57E+12	1.52E+12	1.57E+12	1.52E+12
32	Livestock	6.04E+10	5.46E+10	8.63E+10	1.17E+11	1.21E+11	1.42E+11
32	Wildlife	9.53E+10	8.61E+10	9.53E+10	9.22E+10	9.53E+10	9.22E+10
33	Human	1.52E+12	1.37E+12	1.52E+12	1.47E+12	1.52E+12	1.47E+12
33	Livestock	4.06E+10	3.67E+10	5.80E+10	7.86E+10	8.12E+10	9.54E+10
33	Wildlife	1.31E+11	1.18E+11	1.31E+11	1.27E+11	1.31E+11	1.27E+11

Table E.23 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Lower Slate River watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
1	Human	5.77E+11	5.77E+11	5.58E+11	5.77E+11	5.58E+11	5.77E+11
1	Livestock	1.96E+11	1.96E+11	1.56E+11	1.16E+11	1.12E+11	8.09E+10
1	Wildlife	1.97E+11	1.97E+11	1.91E+11	1.97E+11	1.91E+11	1.97E+11
2	Human	3.50E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11	3.50E+11
2	Livestock	8.81E+10	8.81E+10	7.02E+10	5.18E+10	5.02E+10	3.63E+10
2	Wildlife	7.29E+10	7.29E+10	7.05E+10	7.29E+10	7.05E+10	7.29E+10
3	Human	1.95E+11	1.95E+11	1.88E+11	1.95E+11	1.88E+11	1.95E+11
3	Livestock	2.77E+11	2.77E+11	2.20E+11	1.63E+11	1.57E+11	1.14E+11
3	Wildlife	9.39E+10	9.39E+10	9.08E+10	9.39E+10	9.08E+10	9.39E+10
4	Human	2.49E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11	2.49E+11
4	Livestock	9.89E+10	9.89E+10	7.88E+10	5.82E+10	5.63E+10	4.07E+10
4	Wildlife	3.64E+10	3.64E+10	3.53E+10	3.64E+10	3.53E+10	3.64E+10
5	Human	1.63E+11	1.63E+11	1.57E+11	1.63E+11	1.57E+11	1.63E+11
5	Livestock	4.47E+10	4.47E+10	3.57E+10	2.63E+10	2.55E+10	1.84E+10
5	Wildlife	3.23E+10	3.23E+10	3.13E+10	3.23E+10	3.13E+10	3.23E+10
6	Human	3.50E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11	3.50E+11
6	Livestock	1.41E+11	1.41E+11	1.13E+11	8.32E+10	8.05E+10	5.82E+10
6	Wildlife	9.52E+10	9.52E+10	9.21E+10	9.52E+10	9.21E+10	9.52E+10
7	Human	1.52E+12	1.52E+12	1.47E+12	1.52E+12	1.47E+12	1.52E+12
7	Livestock	7.92E+11	7.92E+11	6.31E+11	4.66E+11	4.51E+11	3.26E+11
7	Wildlife	2.84E+11	2.84E+11	2.74E+11	2.84E+11	2.74E+11	2.84E+11
8	Human	7.13E+10	7.13E+10	6.90E+10	7.13E+10	6.90E+10	7.13E+10
8	Livestock	1.39E+10	1.39E+10	1.11E+10	8.18E+09	7.92E+09	5.73E+09
8	Wildlife	6.26E+10	6.26E+10	6.06E+10	6.26E+10	6.06E+10	6.26E+10

Table E.24 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Lower Slate River watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
9	Human	9.50E+11	9.50E+11	9.19E+11	9.50E+11	9.19E+11	9.50E+11
9	Livestock	1.35E+11	1.35E+11	1.08E+11	7.96E+10	7.70E+10	5.57E+10
9	Wildlife	1.75E+11	1.75E+11	1.70E+11	1.75E+11	1.70E+11	1.75E+11
10	Human	3.57E+11	3.57E+11	3.46E+11	3.57E+11	3.46E+11	3.57E+11
10	Livestock	7.93E+10	7.93E+10	6.32E+10	4.66E+10	4.51E+10	3.26E+10
10	Wildlife	7.39E+10	7.39E+10	7.15E+10	7.39E+10	7.15E+10	7.39E+10
11	Human	2.88E+11	2.88E+11	2.79E+11	2.88E+11	2.79E+11	2.88E+11
11	Livestock	4.26E+10	4.26E+10	3.40E+10	2.51E+10	2.43E+10	1.75E+10
11	Wildlife	5.05E+10	5.05E+10	4.88E+10	5.05E+10	4.88E+10	5.05E+10
12	Human	5.12E+10	5.12E+10	4.95E+10	5.12E+10	4.95E+10	5.12E+10
12	Livestock	5.53E+10	5.53E+10	4.41E+10	3.26E+10	3.15E+10	2.28E+10
12	Wildlife	2.55E+10	2.55E+10	2.47E+10	2.55E+10	2.47E+10	2.55E+10
13	Human	2.25E+11	2.25E+11	2.18E+11	2.25E+11	2.18E+11	2.25E+11
13	Livestock	2.51E+10	2.51E+10	2.00E+10	1.48E+10	1.43E+10	1.03E+10
13	Wildlife	9.71E+10	9.71E+10	9.40E+10	9.71E+10	9.40E+10	9.71E+10
14	Human	2.43E+11	2.43E+11	2.35E+11	2.43E+11	2.35E+11	2.43E+11
14	Livestock	5.29E+11	5.29E+11	4.21E+11	3.11E+11	3.01E+11	2.18E+11
14	Wildlife	9.71E+10	9.71E+10	9.39E+10	9.71E+10	9.39E+10	9.71E+10
15	Human	2.44E+11	2.44E+11	2.36E+11	2.44E+11	2.36E+11	2.44E+11
15	Livestock	2.52E+11	2.52E+11	2.00E+11	1.48E+11	1.43E+11	1.04E+11
15	Wildlife	8.10E+10	8.10E+10	7.84E+10	8.10E+10	7.84E+10	8.10E+10
16	Human	6.22E+10	6.22E+10	6.01E+10	6.22E+10	6.01E+10	6.22E+10
16	Livestock	3.47E+10	3.47E+10	2.77E+10	2.04E+10	1.98E+10	1.43E+10
16	Wildlife	3.37E+10	3.37E+10	3.26E+10	3.37E+10	3.26E+10	3.37E+10
17	Human	4.84E+10	4.84E+10	4.69E+10	4.84E+10	4.69E+10	4.84E+10
17	Livestock	2.31E+10	2.31E+10	1.84E+10	1.36E+10	1.32E+10	9.53E+09
17	Wildlife	1.28E+10	1.28E+10	1.24E+10	1.28E+10	1.24E+10	1.28E+10
18	Human	4.96E+11	4.96E+11	4.80E+11	4.96E+11	4.80E+11	4.96E+11
18	Livestock	3.40E+11	3.40E+11	2.71E+11	2.00E+11	1.94E+11	1.40E+11
18	Wildlife	2.80E+11	2.80E+11	2.71E+11	2.80E+11	2.71E+11	2.80E+11
19	Human	9.87E+10	9.87E+10	9.55E+10	9.87E+10	9.55E+10	9.87E+10
19	Livestock	7.81E+10	7.81E+10	6.22E+10	4.59E+10	4.45E+10	3.22E+10
19	Wildlife	4.71E+10	4.71E+10	4.56E+10	4.71E+10	4.56E+10	4.71E+10
20	Human	9.51E+10	9.51E+10	9.20E+10	9.51E+10	9.20E+10	9.51E+10
20	Livestock	4.44E+10	4.44E+10	3.54E+10	2.61E+10	2.53E+10	1.83E+10
20	Wildlife	2.72E+10	2.72E+10	2.64E+10	2.72E+10	2.64E+10	2.72E+10
21	Human	1.32E+12	1.32E+12	1.28E+12	1.32E+12	1.28E+12	1.32E+12
21	Livestock	3.56E+11	3.56E+11	2.84E+11	2.10E+11	2.03E+11	1.47E+11
21	Wildlife	2.70E+11	2.70E+11	2.61E+11	2.70E+11	2.61E+11	2.70E+11
22	Human	6.64E+11	6.64E+11	6.42E+11	6.64E+11	6.42E+11	6.64E+11
22	Livestock	9.54E+10	9.54E+10	7.60E+10	5.61E+10	5.43E+10	3.93E+10
22	Wildlife	2.49E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11	2.49E+11
23	Human	1.18E+12	1.18E+12	1.14E+12	1.18E+12	1.14E+12	1.18E+12
23	Livestock	1.84E+11	1.84E+11	1.47E+11	1.08E+11	1.05E+11	7.59E+10
23	Wildlife	1.34E+11	1.34E+11	1.30E+11	1.34E+11	1.30E+11	1.34E+11

Table E.25 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Lower Slate River watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
24	Human	4.97E+11	4.97E+11	4.81E+11	4.97E+11	4.81E+11	4.97E+11
24	Livestock	9.32E+11	9.32E+11	7.42E+11	5.48E+11	5.30E+11	3.84E+11
24	Wildlife	4.17E+11	4.17E+11	4.03E+11	4.17E+11	4.03E+11	4.17E+11
25	Human	2.82E+11	2.82E+11	2.73E+11	2.82E+11	2.73E+11	2.82E+11
25	Livestock	3.20E+11	3.20E+11	2.55E+11	1.88E+11	1.82E+11	1.32E+11
25	Wildlife	1.28E+11	1.28E+11	1.24E+11	1.28E+11	1.24E+11	1.28E+11
26	Human	1.55E+11	1.55E+11	1.50E+11	1.55E+11	1.50E+11	1.55E+11
26	Livestock	4.58E+10	4.58E+10	3.65E+10	2.69E+10	2.61E+10	1.89E+10
26	Wildlife	3.78E+10	3.78E+10	3.66E+10	3.78E+10	3.66E+10	3.78E+10
27	Human	2.04E+12	2.04E+12	1.98E+12	2.04E+12	1.98E+12	2.04E+12
27	Livestock	4.17E+11	4.17E+11	3.32E+11	2.45E+11	2.37E+11	1.72E+11
27	Wildlife	1.81E+11	1.81E+11	1.75E+11	1.81E+11	1.75E+11	1.81E+11
28	Human	6.42E+11	6.42E+11	6.21E+11	6.42E+11	6.21E+11	6.42E+11
28	Livestock	1.15E+11	1.15E+11	9.15E+10	6.76E+10	6.54E+10	4.73E+10
28	Wildlife	8.45E+10	8.45E+10	8.17E+10	8.45E+10	8.17E+10	8.45E+10
29	Human	1.30E+11	1.30E+11	1.26E+11	1.30E+11	1.26E+11	1.30E+11
29	Livestock	2.40E+10	2.40E+10	1.91E+10	1.41E+10	1.37E+10	9.89E+09
29	Wildlife	5.61E+10	5.61E+10	5.43E+10	5.61E+10	5.43E+10	5.61E+10
30	Human	6.93E+11	6.93E+11	6.70E+11	6.93E+11	6.70E+11	6.93E+11
30	Livestock	3.09E+11	3.09E+11	2.46E+11	1.82E+11	1.76E+11	1.27E+11
30	Wildlife	1.80E+11	1.80E+11	1.75E+11	1.80E+11	1.75E+11	1.80E+11
31	Human	2.95E+11	2.95E+11	2.86E+11	2.95E+11	2.86E+11	2.95E+11
31	Livestock	7.47E+10	7.47E+10	5.95E+10	4.39E+10	4.25E+10	3.08E+10
31	Wildlife	3.48E+10	3.48E+10	3.37E+10	3.48E+10	3.37E+10	3.48E+10
32	Human	1.57E+12	1.57E+12	1.52E+12	1.57E+12	1.52E+12	1.57E+12
32	Livestock	1.47E+11	1.47E+11	1.17E+11	8.63E+10	8.35E+10	6.04E+10
32	Wildlife	9.53E+10	9.53E+10	9.22E+10	9.53E+10	9.22E+10	9.53E+10
33	Human	1.52E+12	1.52E+12	1.47E+12	1.52E+12	1.47E+12	1.52E+12
33	Livestock	9.86E+10	9.86E+10	7.86E+10	5.80E+10	5.61E+10	4.06E+10
33	Wildlife	1.31E+11	1.31E+11	1.27E+11	1.31E+11	1.27E+11	1.31E+11

Table E.26 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Upper Slate River watershed (subwatersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,21,22 & 23).

Reach ID	Source Type	January	February	March	April	May	June
1	Human	5.77E+11	5.21E+11	5.77E+11	5.58E+11	5.77E+11	5.58E+11
1	Livestock	8.09E+10	7.30E+10	1.16E+11	1.56E+11	1.62E+11	1.90E+11
1	Wildlife	1.97E+11	1.78E+11	1.97E+11	1.91E+11	1.97E+11	1.91E+11
2	Human	3.50E+11	3.16E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11
2	Livestock	3.63E+10	3.28E+10	5.18E+10	7.02E+10	7.26E+10	8.53E+10
2	Wildlife	7.29E+10	6.58E+10	7.29E+10	7.05E+10	7.29E+10	7.05E+10
3	Human	1.95E+11	1.76E+11	1.95E+11	1.88E+11	1.95E+11	1.88E+11
3	Livestock	1.14E+11	1.03E+11	1.63E+11	2.20E+11	2.28E+11	2.68E+11
3	Wildlife	9.39E+10	8.48E+10	9.39E+10	9.08E+10	9.39E+10	9.08E+10
4	Human	2.49E+11	2.25E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11
4	Livestock	4.07E+10	3.68E+10	5.82E+10	7.88E+10	8.15E+10	9.57E+10
4	Wildlife	3.64E+10	3.29E+10	3.64E+10	3.53E+10	3.64E+10	3.53E+10
5	Human	1.63E+11	1.47E+11	1.63E+11	1.57E+11	1.63E+11	1.57E+11
5	Livestock	1.84E+10	1.66E+10	2.63E+10	3.57E+10	3.68E+10	4.33E+10
5	Wildlife	3.23E+10	2.92E+10	3.23E+10	3.13E+10	3.23E+10	3.13E+10
6	Human	3.50E+11	3.16E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11
6	Livestock	5.82E+10	5.26E+10	8.32E+10	1.13E+11	1.16E+11	1.37E+11
6	Wildlife	9.52E+10	8.59E+10	9.52E+10	9.21E+10	9.52E+10	9.21E+10
13	Human	2.25E+11	2.03E+11	2.25E+11	2.18E+11	2.25E+11	2.18E+11
13	Livestock	1.03E+10	9.33E+09	1.48E+10	2.00E+10	2.07E+10	2.43E+10
13	Wildlife	9.71E+10	8.77E+10	9.71E+10	9.40E+10	9.71E+10	9.40E+10
14	Human	2.43E+11	2.20E+11	2.43E+11	2.35E+11	2.43E+11	2.35E+11
14	Livestock	2.18E+11	1.97E+11	3.11E+11	4.21E+11	4.35E+11	5.11E+11
14	Wildlife	9.71E+10	8.77E+10	9.71E+10	9.39E+10	9.71E+10	9.39E+10
15	Human	2.44E+11	2.20E+11	2.44E+11	2.36E+11	2.44E+11	2.36E+11
15	Livestock	1.04E+11	9.35E+10	1.48E+11	2.00E+11	2.07E+11	2.43E+11
15	Wildlife	8.10E+10	7.32E+10	8.10E+10	7.84E+10	8.10E+10	7.84E+10
16	Human	6.22E+10	5.61E+10	6.22E+10	6.01E+10	6.22E+10	6.01E+10
16	Livestock	1.43E+10	1.29E+10	2.04E+10	2.77E+10	2.86E+10	3.36E+10
16	Wildlife	3.37E+10	3.05E+10	3.37E+10	3.26E+10	3.37E+10	3.26E+10
17	Human	4.84E+10	4.38E+10	4.84E+10	4.69E+10	4.84E+10	4.69E+10
17	Livestock	9.53E+09	8.61E+09	1.36E+10	1.84E+10	1.91E+10	2.24E+10
17	Wildlife	1.28E+10	1.16E+10	1.28E+10	1.24E+10	1.28E+10	1.24E+10
18	Human	4.96E+11	4.48E+11	4.96E+11	4.80E+11	4.96E+11	4.80E+11
18	Livestock	1.40E+11	1.26E+11	2.00E+11	2.71E+11	2.80E+11	3.29E+11
18	Wildlife	2.80E+11	2.53E+11	2.80E+11	2.71E+11	2.80E+11	2.71E+11
21	Human	1.32E+12	1.20E+12	1.32E+12	1.28E+12	1.32E+12	1.28E+12
21	Livestock	1.47E+11	1.33E+11	2.10E+11	2.84E+11	2.93E+11	3.45E+11
21	Wildlife	2.70E+11	2.44E+11	2.70E+11	2.61E+11	2.70E+11	2.61E+11
22	Human	6.64E+11	5.99E+11	6.64E+11	6.42E+11	6.64E+11	6.42E+11
22	Livestock	3.93E+10	3.55E+10	5.61E+10	7.60E+10	7.86E+10	9.23E+10
22	Wildlife	2.49E+11	2.25E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11
23	Human	1.18E+12	1.06E+12	1.18E+12	1.14E+12	1.18E+12	1.14E+12
23	Livestock	7.59E+10	6.86E+10	1.08E+11	1.47E+11	1.52E+11	1.78E+11
23	Wildlife	1.34E+11	1.21E+11	1.34E+11	1.30E+11	1.34E+11	1.30E+11

Table E.27 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Upper Slate River watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
1	Human	5.77E+11	5.77E+11	5.58E+11	5.77E+11	5.58E+11	5.77E+11
1	Livestock	1.96E+11	1.96E+11	1.56E+11	1.16E+11	1.12E+11	8.09E+10
1	Wildlife	1.97E+11	1.97E+11	1.91E+11	1.97E+11	1.91E+11	1.97E+11
2	Human	3.50E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11	3.50E+11
2	Livestock	8.81E+10	8.81E+10	7.02E+10	5.18E+10	5.02E+10	3.63E+10
2	Wildlife	7.29E+10	7.29E+10	7.05E+10	7.29E+10	7.05E+10	7.29E+10
3	Human	1.95E+11	1.95E+11	1.88E+11	1.95E+11	1.88E+11	1.95E+11
3	Livestock	2.77E+11	2.77E+11	2.20E+11	1.63E+11	1.57E+11	1.14E+11
3	Wildlife	9.39E+10	9.39E+10	9.08E+10	9.39E+10	9.08E+10	9.39E+10
4	Human	2.49E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11	2.49E+11
4	Livestock	9.89E+10	9.89E+10	7.88E+10	5.82E+10	5.63E+10	4.07E+10
4	Wildlife	3.64E+10	3.64E+10	3.53E+10	3.64E+10	3.53E+10	3.64E+10
5	Human	1.63E+11	1.63E+11	1.57E+11	1.63E+11	1.57E+11	1.63E+11
5	Livestock	4.47E+10	4.47E+10	3.57E+10	2.63E+10	2.55E+10	1.84E+10
5	Wildlife	3.23E+10	3.23E+10	3.13E+10	3.23E+10	3.13E+10	3.23E+10
6	Human	3.50E+11	3.50E+11	3.39E+11	3.50E+11	3.39E+11	3.50E+11
6	Livestock	1.41E+11	1.41E+11	1.13E+11	8.32E+10	8.05E+10	5.82E+10
6	Wildlife	9.52E+10	9.52E+10	9.21E+10	9.52E+10	9.21E+10	9.52E+10
13	Human	2.25E+11	2.25E+11	2.18E+11	2.25E+11	2.18E+11	2.25E+11
13	Livestock	2.51E+10	2.51E+10	2.00E+10	1.48E+10	1.43E+10	1.03E+10
13	Wildlife	9.71E+10	9.71E+10	9.40E+10	9.71E+10	9.40E+10	9.71E+10
14	Human	2.43E+11	2.43E+11	2.35E+11	2.43E+11	2.35E+11	2.43E+11
14	Livestock	5.29E+11	5.29E+11	4.21E+11	3.11E+11	3.01E+11	2.18E+11
14	Wildlife	9.71E+10	9.71E+10	9.39E+10	9.71E+10	9.39E+10	9.71E+10
15	Human	2.44E+11	2.44E+11	2.36E+11	2.44E+11	2.36E+11	2.44E+11
15	Livestock	2.52E+11	2.52E+11	2.00E+11	1.48E+11	1.43E+11	1.04E+11
15	Wildlife	8.10E+10	8.10E+10	7.84E+10	8.10E+10	7.84E+10	8.10E+10
16	Human	6.22E+10	6.22E+10	6.01E+10	6.22E+10	6.01E+10	6.22E+10
16	Livestock	3.47E+10	3.47E+10	2.77E+10	2.04E+10	1.98E+10	1.43E+10
16	Wildlife	3.37E+10	3.37E+10	3.26E+10	3.37E+10	3.26E+10	3.37E+10
17	Human	4.84E+10	4.84E+10	4.69E+10	4.84E+10	4.69E+10	4.84E+10
17	Livestock	2.31E+10	2.31E+10	1.84E+10	1.36E+10	1.32E+10	9.53E+09
17	Wildlife	1.28E+10	1.28E+10	1.24E+10	1.28E+10	1.24E+10	1.28E+10
18	Human	4.96E+11	4.96E+11	4.80E+11	4.96E+11	4.80E+11	4.96E+11
18	Livestock	3.40E+11	3.40E+11	2.71E+11	2.00E+11	1.94E+11	1.40E+11
18	Wildlife	2.80E+11	2.80E+11	2.71E+11	2.80E+11	2.71E+11	2.80E+11
21	Human	1.32E+12	1.32E+12	1.28E+12	1.32E+12	1.28E+12	1.32E+12
21	Livestock	3.56E+11	3.56E+11	2.84E+11	2.10E+11	2.03E+11	1.47E+11
21	Wildlife	2.70E+11	2.70E+11	2.61E+11	2.70E+11	2.61E+11	2.70E+11
22	Human	6.64E+11	6.64E+11	6.42E+11	6.64E+11	6.42E+11	6.64E+11
22	Livestock	9.54E+10	9.54E+10	7.60E+10	5.61E+10	5.43E+10	3.93E+10
22	Wildlife	2.49E+11	2.49E+11	2.41E+11	2.49E+11	2.41E+11	2.49E+11
23	Human	1.18E+12	1.18E+12	1.14E+12	1.18E+12	1.14E+12	1.18E+12
23	Livestock	1.84E+11	1.84E+11	1.47E+11	1.08E+11	1.05E+11	7.59E+10
23	Wildlife	1.34E+11	1.34E+11	1.30E+11	1.34E+11	1.30E+11	1.34E+11

Table E.28 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Totier Creek watershed (subwatersheds 39,40 & 41).

Reach ID	Source Type	January	February	March	April	May	June
39	Human	1.11E+12	1.00E+12	1.11E+12	1.07E+12	1.11E+12	1.07E+12
39	Livestock	1.29E+11	1.17E+11	1.85E+11	2.50E+11	2.59E+11	3.04E+11
39	Wildlife	3.43E+11	3.10E+11	3.43E+11	3.32E+11	3.43E+11	3.32E+11
40	Human	1.92E+10	1.73E+10	1.92E+10	1.86E+10	1.92E+10	1.86E+10
40	Livestock	4.35E+09	3.93E+09	6.21E+09	8.41E+09	8.69E+09	1.02E+10
40	Wildlife	5.42E+10	4.90E+10	5.42E+10	5.25E+10	5.42E+10	5.25E+10
41	Human	5.06E+11	4.57E+11	5.06E+11	4.90E+11	5.06E+11	4.90E+11
41	Livestock	5.26E+10	4.75E+10	7.51E+10	1.02E+11	1.05E+11	1.24E+11
41	Wildlife	1.28E+11	1.16E+11	1.28E+11	1.24E+11	1.28E+11	1.24E+11

Table E.29 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Totier Creek watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
39	Human	1.11E+12	1.11E+12	1.07E+12	1.11E+12	1.07E+12	1.11E+12
39	Livestock	3.14E+11	3.14E+11	2.50E+11	1.85E+11	1.79E+11	1.29E+11
39	Wildlife	3.43E+11	3.43E+11	3.32E+11	3.43E+11	3.32E+11	3.43E+11
40	Human	1.92E+10	1.92E+10	1.86E+10	1.92E+10	1.86E+10	1.92E+10
40	Livestock	1.06E+10	1.06E+10	8.41E+09	6.21E+09	6.01E+09	4.35E+09
40	Wildlife	5.42E+10	5.42E+10	5.25E+10	5.42E+10	5.25E+10	5.42E+10
41	Human	5.06E+11	5.06E+11	4.90E+11	5.06E+11	4.90E+11	5.06E+11
41	Livestock	1.28E+11	1.28E+11	1.02E+11	7.51E+10	7.27E+10	5.26E+10
41	Wildlife	1.28E+11	1.28E+11	1.24E+11	1.28E+11	1.24E+11	1.28E+11

Table E.30 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Troublesome Creek watershed (subwatersheds 17 & 23).

Reach ID	Source Type	January	February	March	April	May	June
17	Human	4.84E+10	4.38E+10	4.84E+10	4.69E+10	4.84E+10	4.69E+10
17	Livestock	9.53E+09	8.61E+09	1.36E+10	1.84E+10	1.91E+10	2.24E+10
17	Wildlife	1.28E+10	1.16E+10	1.28E+10	1.24E+10	1.28E+10	1.24E+10
23	Human	1.18E+12	1.06E+12	1.18E+12	1.14E+12	1.18E+12	1.14E+12
23	Livestock	7.59E+10	6.86E+10	1.08E+11	1.47E+11	1.52E+11	1.78E+11
23	Wildlife	1.34E+11	1.21E+11	1.34E+11	1.30E+11	1.34E+11	1.30E+11

Table E.31 Monthly, directly deposited *E. coli* loads (cfu/day) in each reach of the Troublesome Creek watershed (cont).

Reach ID	Source Type	July	August	September	October	November	December
17	Human	4.84E+10	4.84E+10	4.69E+10	4.84E+10	4.69E+10	4.84E+10
17	Livestock	2.31E+10	2.31E+10	1.84E+10	1.36E+10	1.32E+10	9.53E+09
17	Wildlife	1.28E+10	1.28E+10	1.24E+10	1.28E+10	1.24E+10	1.28E+10
23	Human	1.18E+12	1.18E+12	1.14E+12	1.18E+12	1.14E+12	1.18E+12
23	Livestock	1.84E+11	1.84E+11	1.47E+11	1.08E+11	1.05E+11	7.59E+10
23	Wildlife	1.34E+11	1.34E+11	1.30E+11	1.34E+11	1.30E+11	1.34E+11

Table E.32 Existing annual loads from direct-deposition sources for the Austin Creek watershed (subwatershed 13).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	2.65E+12
Livestock	
Beef	2.09E+11
Wildlife	
beaver	1.02E+09
deer	6.03E+09
duck	7.46E+07
goose	6.96E+09
muskrat	1.06E+12
Raccoon	6.75E+10
Turkey	8.10E+06
Total	**4.00E+12**

Table E.33 Existing annual loads from direct-deposition sources for the Ballinger Creek watershed (subwatersheds 37 & 38).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	1.37E+13
Livestock	
Beef	4.04E+12
Wildlife	
muskrat	3.01E+12
raccoon	1.76E+11
turkey	7.85E+06
beaver	2.20E+09
deer	1.58E+10
duck	2.11E+08
goose	1.97E+10
Total	**2.10E+13**

Table E.34 Existing annual loads from direct-deposition sources for the Frisby Branch watershed (subwatershed 2).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	4.12E+12
Livestock	
Beef	7.34E+11
Wildlife	
beaver	7.58E+08
deer	4.33E+09
duck	5.62E+07
goose	5.25E+09
muskrat	7.99E+11
raccoon	4.80E+10
turkey	1.85E+06
Total	**5.71E+12**

Table E.35 Existing annual loads from direct-deposition sources for the North River watershed (subwatersheds 13,14,15,16 & 22).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	1.69E+13
Livestock	
Beef	7.79E+12
Wildlife	
beaver	5.60E+09
deer	3.00E+10
duck	4.32E+08
goose	4.04E+10
muskrat	6.15E+12
raccoon	3.46E+11
turkey	2.47E+07
Total	**3.13E+13**

Table E.36 Existing annual loads from direct-deposition sources for the Rock Island Creek watershed (subwatersheds 34,35 & 36).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	1.63E+13
Livestock	
Beef	2.60E+12
Wildlife	
beaver	2.78E+09
deer	1.79E+10
duck	2.34E+08
goose	2.18E+10
muskrat	3.32E+12
raccoon	1.96E+11
turkey	1.16E+07
Total	**2.25E+13**

Table E.37 Existing annual loads from direct-deposition sources for the Lower Slate River watershed (subwatersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32 & 33).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	2.08E+14
Livestock	
Beef	5.34E+13
Wildlife	
beaver	3.93E+10
deer	2.13E+11
duck	3.00E+09
goose	2.80E+11
muskrat	4.27E+13
raccoon	2.40E+12
turkey	1.03E+08
Total	**3.07E+14**

Table E.38 Existing annual loads from direct-deposition sources for the Upper Slate River watershed (subwatersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 21,22 & 23).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	7.50E+13
Livestock	
Beef	2.24E+13
Wildlife	
beaver	1.80E+10
deer	9.42E+10
duck	1.38E+09
goose	1.29E+11
muskrat	1.97E+13
raccoon	1.08E+12
turkey	5.28E+07
Total	**1.18E+14**

Table E.39 Existing annual loads from direct-deposition sources for the Totier Creek watershed (subwatersheds 39,40 & 41).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	1.92E+13
Livestock	
Beef	3.77E+12
Wildlife	
beaver	4.35E+09
deer	2.68E+10
duck	4.08E+08
goose	3.81E+10
muskrat	5.81E+12
raccoon	3.09E+11
turkey	3.91E+06
Total	**2.92E+13**

Table E.40 Existing annual loads from direct-deposition sources for the Troublesome Creek watershed (subwatersheds 17 & 23).

Source	Annual Total Loads (cfu/day)
Human	
Straight pipes	1.45E+13
Livestock	
Beef	1.73E+12
Wildlife	
beaver	1.24E+09
deer	5.60E+09
duck	1.16E+08
goose	1.08E+10
muskrat	1.64E+12
raccoon	7.28E+10
turkey	4.50E+06
Total	**1.80E+13**